ELECTRONIC ENGINEERING APPLICATIONS

INPUT

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INPUT provides planning information, analysis, and recommendations to managers and executives in the information processing industries. Through market research, technology forecasting, and competitive analysis, INPUT supports client management in making informed decisions. Continuing services are provided to users and vendors of computers, communications, and office products and services.

The company carries out continuous and in-depth research. Working closely with clients on important issues, INPUT's staff members analyze and interpret the research data, then develop recommendations and innovative ideas to meet clients' needs. Clients receive reports, presentations, access to data on which analyses are based, and continuous consulting.

Many of INPUT's professional staff members have nearly 20 years experience in their areas of specialization. Most have held senior management positions in operations, marketing, or planning. This expertise enables INPUT to supply practical solutions to complex business problems.

Formed in 1974, INPUT has become a leading international consulting firm. Clients include over 100 of the world's largest and most technically advanced companies.

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INPUT Planning Services for Management

IMPROVING THE PRODUCTIVITY OF ENGINEERING AND MANUFACTURING USING CAD/CAM ELECTRONIC ENGINEERING APPLICATIONS

A MULTICLIENT STUDY

DECEMBER 1981

IMPROVING THE PRODUCTIVITY OF ENGINEERING AND MANUFACTURING USING CAD/CAM ELECTRONIC ENGINEERING APPLICATIONS

CONTENTS

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IMPROVING THE PRODUCTIVITY OF ENGINEERING AND MANUFACTURING USING CAD/CAM ELECTRONIC ENGINEERING APPLICATIONS

EXHIBITS

I INTRODUCTION

I INTRODUCTION

A. PURPOSE

- This volume, produced by INPUT as part of a five-volume CAD/CAM (computer-aided design/computer-aided manufacturing) multiclient study, analyzes the issues and market opportunities specific to electronic engineering applications. Projections are made over the next five years.

- For this study, the electronics industry is defined as the research, design, manufacture, sales, and distribution of printed and integrated circuits (PCB - printed circuit boards and IC - integrated circuits).

  - Due to rapidly developing technology, this industry has revolutionized electronic equipment over the past decade.

  - The complexity of printed and integrated circuits has grown so rapidly that it has long since outstripped manual design and manufacturing methods, making use of ever improving CAD/CAM systems mandatory for survival.

  - As a result, the needs and characteristics for CAD/CAM systems for electronics applications are very specific to this industry, particularly in software development.

- The primary purpose of this volume is to analyze user needs and vendor responses to these needs, in order to delineate both market opportunities and methods for improving productivity in electronic applications.

B. RESEARCH METHODOLOGY

- The results presented in this electronic CAD/CAM study are based on the following research efforts:

  - In-depth interviews with VLSI and PCB users and vendors.

  - Review of previous INPUT research on CAD/CAM, which was focused on:

    . User issues.

    . Vendor strategies.

    . Productivity improvements.

    . Market forecasts.

- The interview program includes 72 respondents; 59 users and 13 vendors. A summary is shown in Exhibit I-1.

  - Over 50% of the interviews were in-depth, on-site interviews conducted by INPUT senior staff.

    . All of the vendor interviews and 40% of the user interviews were conducted on-site by senior staff.

EXHIBIT I-1

INTERVIEW PROGRAM

TYPE	NUMBER OF INTERVIEWS		
	ON-SITE	TELE-PHONE	TOTAL
User	-	-	-
• IC	14	12	26
• PCB	7	22	29
• IC & PCB	3	1	4
Subtotal	24	35	59
Vendor	13	-	13
Total	37	35	72

- An abridged version of the user questionnaire was used for telephone interviews in order to keep within a reasonable time.

- IC and PCB users were almost equally represented.

- Vendors were nearly all systems companies, but some peripheral equipment companies were included as well to round out the views of the industry.

- All respondents included in this volume are U.S.-based companies.

  . Results of interviews in Japan and Europe will be published subsequently.

• For the purposes of this study, users were categorized by size in terms of annual sales revenue as follows:

  - Small - less than \$100 million.

  - Medium - between \$100 and \$1,000 million.

  - Large - greater than \$1 billion.

  - The average size user respondent was \$365 million. A size profile of user respondents is given in Exhibit I-2.

EXHIBIT I-2

USER INTERVIEWS BY COMPANY SIZE

TYPE OF USER	NUMBER OF INTERVIEWS BY COMPANY SIZE ($ billions)			
	SMALL <$0.1	MEDIUM $0.1 - $1	LARGE >$1	TOTAL
IC	5	7	14	26
PCB	5	3	21	29
IC & PCB	0	0	4	4
Total	10	10	39	59

*AVERAGE SIZE OF USER RESPONDENT = $365 MILLION IN SALES

II EXECUTIVE SUMMARY

II EXECUTIVE SUMMARY

A. PROJECTED GROWTH

- The market for electronic CAD/CAM systems in 1980 is estimated at $243 million, and is forecast to grow at a compounded rate of 32% per year, reaching $1.3 billion in 1986.

  - Market projections are shown in Exhibit II-1.

  - Growth is attributable to the fact that next generation, state-of-the-art CAD/CAM systems are not discretionary in the printed and integrated circuit industry; they are essential for survival in a competitive world market.

- The two dominant modes of delivery for CAD/CAM systems are turnkey and in-house (customer) equipment.

  - The electronic market today is dominated (almost two-thirds) by turnkey systems offered by established turnkey vendors.

  - In the future, INPUT predicts, in-house equipment as well as software products sales will rapidly overtake the turnkey segment of the electronic marketplace, growing at an average annual growth rate (AAGR) of 49%, and accounting for 56% of the market in 1986.

EXHIBIT II-1

MARKET FORECAST OF SALES VALUE OF ELECTRONIC CAD/CAM SYSTEMS, SOFTWARE AND SERVICES, 1981-1986 ($ millions)

TYPE OF SYSTEM	1980 BASE YEAR	1981	1982	1983	1984	1985	1986	AAGR 1980-1986 (percent)
Turnkey	$165	$200	$240	$290	$350	$430	$ 520	21%
In-House Equipment	67	100	150	220	330	490	730	49
Remote Computing Services	7	10	10	15	15	20	25	24
Software Products	4	5	7	10	15	20	25	36
Total	$243	$315	$407	$535	$710	$960	$1,300	32%

- This rapid growth will be directly attributable to massive in-house development programs by the larger companies aimed at developing advanced function systems which will not be made available from the turnkey vendors.

- Use of remote computing services is small by comparison because of limitations imposed by the large communications requirements for interactive graphics.

B. SUMMARY OF MAJOR TRENDS AND DRIVING FORCES

- Advances in technology over the last decade in printed and integrated circuits have made possible previously unheard of improvements in electronic equipment.

- Technology advances have also resulted in much greater product complexity.

  - Integrated circuits have doubled in complexity (number of active devices per chip) every year for over a decade.

    - This trend is expected to continue indefinitely, resulting in one-million-device chips by 1986: the equivalent of a computer in today's DEC VAX line on a single chip.

  - Printed circuits also continue to grow in complexity, with shrinking grid spacings and multisignal layers increasing to accommodate greater component densities.

- The capacity of CAD/CAM systems must increase at an even higher exponential rate than the circuits themselves in order to provide adequate design capability.

- The net result today is that the design requirements of the electronics industry have outstripped the capability of available CAD/CAM systems, and solutions must be found if the industry is to remain competitive in world markets and continue to grow.

- Continued improvement in the cost/benefits of equipment is not enough to solve the problems.

  - Greatly improved CAD/CAM software is needed in the next few years.

- Intensive software R&D efforts are underway because of the high stakes involved.

  - These efforts are centered in many universities and supported by government and industry.

- If these efforts are successful, as expected, greatly improved design methods will result.

  - There is no question that the industry is "technology driven."

- Today's CAD/CAM systems generally lack sufficient processing capability, resulting in poor response times which inhibit design and productivity.

  - The solution to this problem is expected to come from hardware improvements over the next five years, which will make it possible to provide sufficient processing power locally at the workstations so there will no longer be a dependence on a timeshared central graphics processor.

- There are today only about 2,000 skilled VLSI designers in the country.

  - This scarcity severely restricts the capability of the industry to solve the design problems.

- Within the next five years, VLSI circuits will be designed by less skilled personnel due to improved software and training methods.

    . In effect, automation in the industry will help overcome the scarcity of designers.

C. SELECTION CRITERIA

- The most important factor in the selection of systems is software, as shown in Exhibit II-2.

    - This is directly attributable to the inadequacy of present CAD/CAM software and the tremendous economic advantages to be derived by better design methods made possible by software improvements.

    - For VLSI design, the areas most in need of software advances are:

        . Testing.

        . Functional and logic simulation.

        . Topography verification.

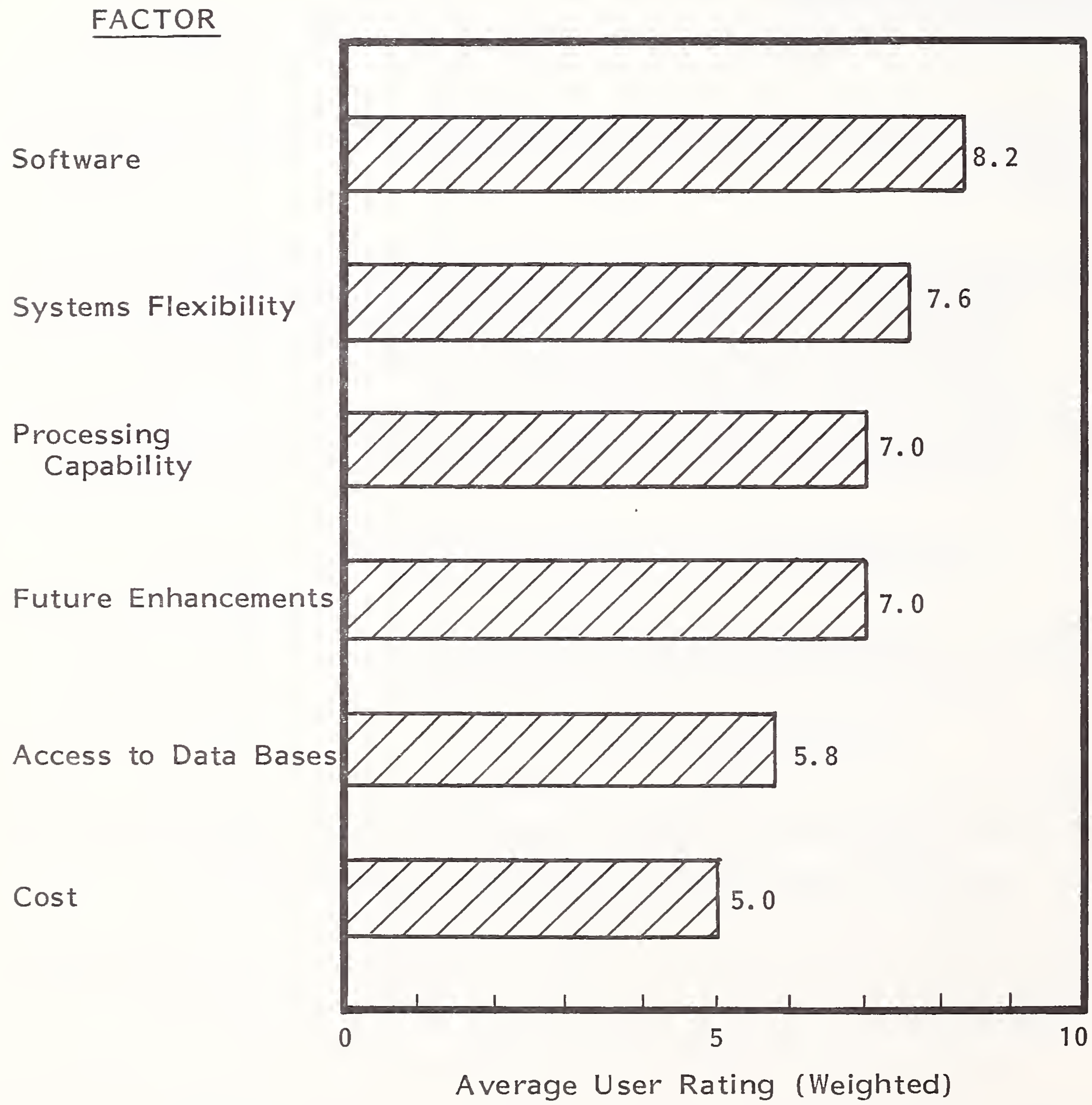
    - For printed circuit design the requirement is for improved automated routing and placement for high-density, multilayer boards.

- Systems flexibility and sufficient processing capability are very significant in system selection but are more easily provided than adequate software.

- Future enhancements are also rated highly, an indication of the speed with which user needs are growing, requiring them to look for system growth even at the time of purchase.

EXHIBIT II-2

IMPORTANT FACTORS IN THE SELECTION OF SYSTEMS AND VENDORS



1 = No Importance,
5 = Average
10 = Highest Importance

* SEE APPENDIX B FOR DETAIL

- Systems cost (meaning the cost of hardware and software) was rated last by the users, who regarded it as least important in comparison to other selection criteria.

  - INPUT agrees with this view, because, although engineering design for printed and integrated circuits has become very capital intensive, technological factors are much more important in cost justification of the system.

- The relatively low ratings respondents gave to access to data bases as an important factor in system selection is an indication that the development of true engineering data bases and the integration of CAD/CAM have not developed very far in the electronic market sector.

  - Users are generally not offered this choice in today's market.

  - INPUT believes that data base development will be a very important factor in CAD/CAM systems over the next five years.

- The most compelling justification for the use of CAD/CAM systems for the design of printed and integrated circuits is that designs would not be feasible otherwise.

- The most important method of cost justification is shortened design spans.

  - Time is money and shortened design spans mean lower development costs.

  - More importantly, shortened design spans mean increased revenues due to lengthened product life cycles.

D. FUTURE REQUIREMENTS

- Processing capability requirements for the design of printed and integrated circuits exceed the capability of present vendor supplied CAD/CAM systems. Increasing demands to keep pace with greater circuit complexity makes this a critical issue for the industry.

- The need is for more local intelligence at the workstation.

  - The trend is clearly going in this direction; expected advances in VLSI technology will make it possible to provide the equivalent of a full DEC VAX capability at the workstation for $20,000 to $30,000 by 1986.

  - The resulting distributed data processing network will alleviate the limitations inherent in a central graphics processor configuration.

- The integration of computer-aided design and computer-aided manufacturing systems holds great potential for improvement, and is badly needed by the industry.

  - The integration issue is somewhat of a paradox to users.

    - On the one hand, more steps in the electronic CAD/CAM process are automated today, but in the overall sense, with common data bases shared by various organizations and the automation of many presently manual steps, INPUT believes that very little progress toward CAD/CAM integration has been made to date.

- Implementation of CAD/CAM integration in the electronics industry is expected to be slow.

  - The systems problems are complex.

- There is much yet to be done in CAD systems and integration is not very high on the list of priorities.

- The costs will be high.

- Inherent organizational consequences will require the attention of top management, because integration of CAD/CAM will affect the traditional roles of engineering, manufacturing, project control, procurement, and other functional organizations.

• Improved technology resulting from university research efforts will be an important driving force in CAD/CAM integration.

• As previously stated, software is the key underlying technology driving CAD/CAM, and the continuing success of the printed and integrated circuit industry depends on major improvements over the next five years.

• Reliability is a problem; users expect greater than 95% system availability and they are falling far short of that expectation.

  - Reported experience with system uptime varies between 75% and 98%, with an average of 87%.

  - INPUT expects system reliability to improve to the point where it is close to the computer industry norm of 98%, due to the efforts of the vendors and inherent improvements in computer equipment reliability within the five-year timeframe.

• Display technology requirements for CAD/CAM systems in the printed and integrated circuit industry are being met by bit-mapped raster scan terminals, and this technology will become even more dominant over the next five years.

  - This technique has established itself as the rapid growth technology in color systems, which are essential for electronic design.

- Color is highly desirable for electronic design, and raster scan terminals are the only true method of providing it.

- Resolution provided by raster scan terminals has improved to the point that it is no longer an issue.

- Memory requirements needed to position the pixels are now easily met.

- Costs have come down to the point of acceptability to almost all users.

- Neither the direct view storage tube nor vector stroke terminals will play an essential future role.

III DRIVING FORCES AND TRENDS

III DRIVING FORCES AND TRENDS

A. GROWING PRODUCT COMPLEXITY

- Integrated circuit devices follow an exponential curve, doubling in complexity (number of active devices per chip) every year, which creates a critical problem in providing adequate design capability for the electronics industry.

- Over a decade ago, Gordon Moore of Intel observed that the number of transistors in the most complex devices was doubling every year.

  - This observation later became known to some as Moore's law and has held true for ten years.

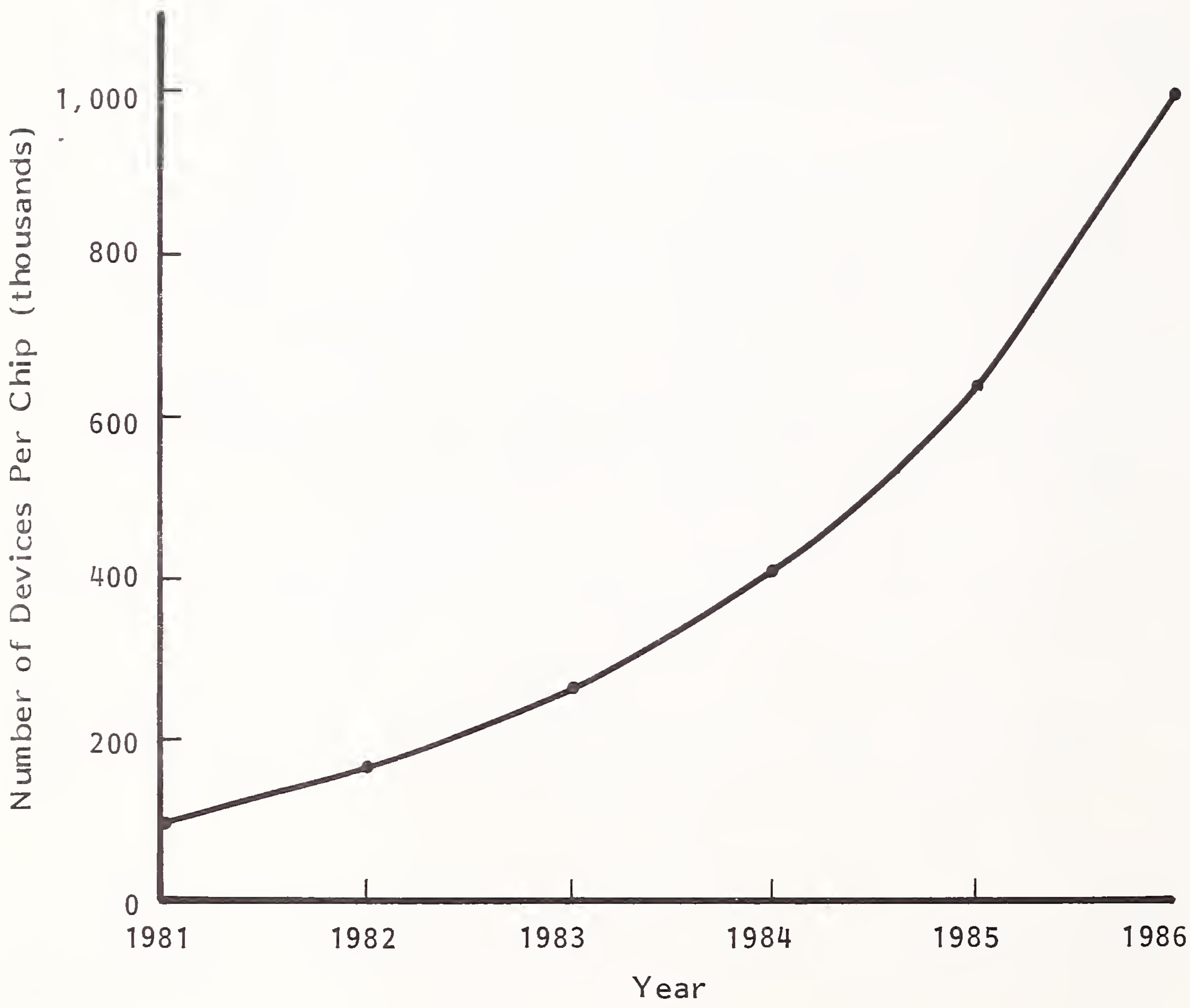
  - Even a modest forecast shows that the industry will be producing chips that will grow from today's 100,000 device chip to a 1,000,000 device chip in 1986, as shown in Exhibit III-1.

- Impressively, there is no basic limitation in sight, since by some estimates, densities can increase by a factor of 100 times before the fundamental limits of the technology are reached.

- The rapid advances in VLSI technology are dramatically evidenced by the recent Hewlett-Packard announcement of the 450,000 transistor chip.

EXHIBIT III-1

GROWING COMPLEXITY OF VLSI DEVICES



- A photo of this remarkable device, which in actual size is only 0.25 of an inch square, is shown in Exhibit III-2.

- Although the device is still under development, its existence is a clear portrayal of what is on the horizon for the VLSI industry.

• Imagine the impact that a 32-bit CPU on a single chip will have on the industry, and its portent of things to come for future CAD systems.

• Some of the salient features of the new VLSI chip are as follows:

  - 32-bit CPU.

  - 450,000 transistors interconnected by two layers of metallization with minimum size and spacing of 1.5 and 1 micron, respectively.

  - 6.35-mm-square chip.

• Great benefits will be realized by reaching higher degrees of circuit integration.

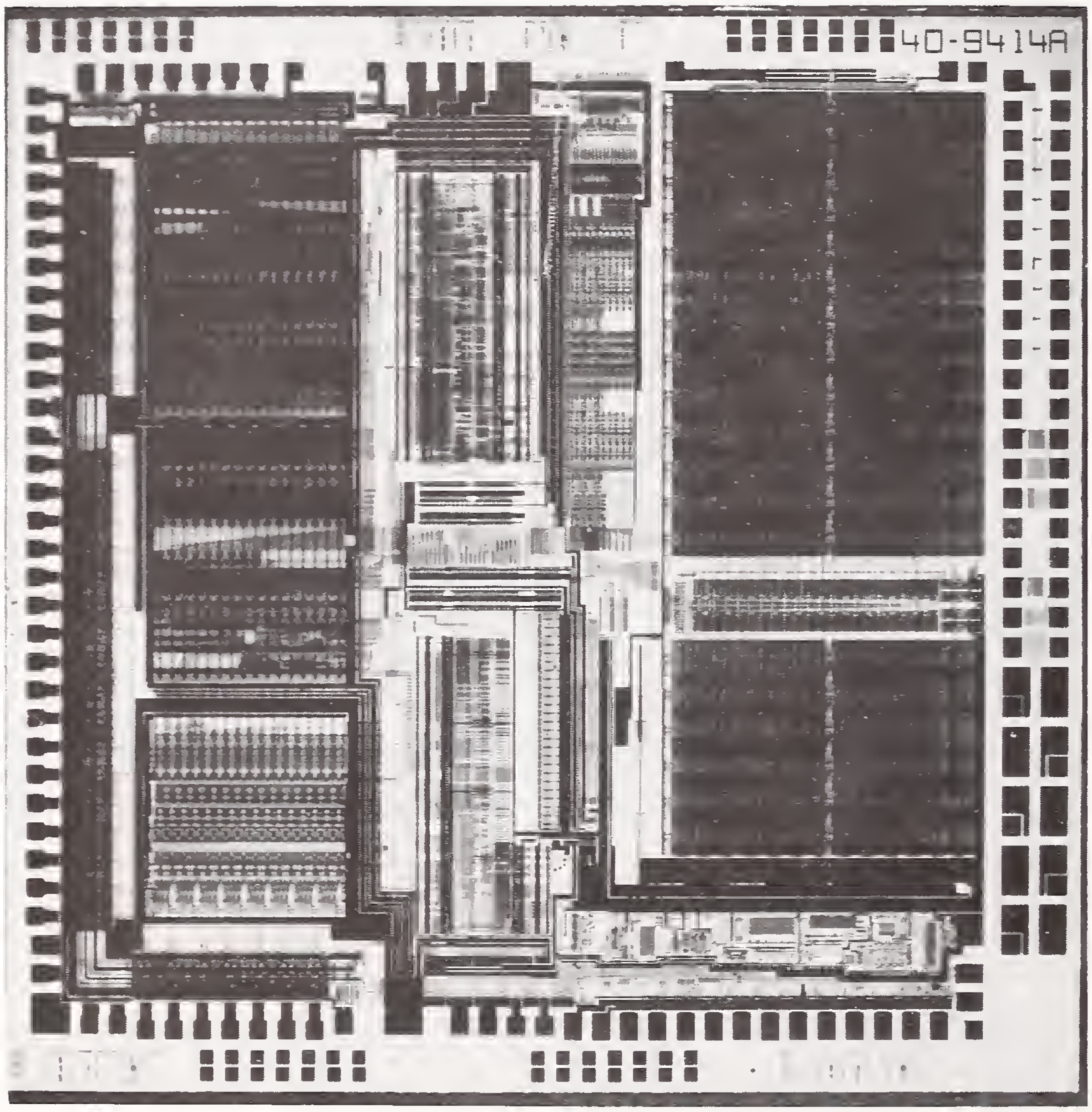
  - The most obvious benefit is the dramatic improvement in cost/performance as the cost of the chip is amortized over a larger number of functions.

  - Equally important are the increases in performance and overall reliability that accrue as devices shrink in size.

• The problem of providing adequate VLSI design processing capability is further compounded by the fact that the complexity of CAD systems must increase at an even higher exponential rate than the ICs themselves in order to handle the designs.

EXHIBIT III-2

HEWLETT-PACKARD 450,000 TRANSISTOR CHIP



Actual Size 0.25 X 0.25 Inches

- The problems of providing adequate CAD systems for PCB design are similar to those for IC design systems, although to a lesser extent.

  - The complexity of many two-sided and multilayer PCBs has outstripped the capability of today's CAD systems.

  - Placement and routing are a problem.

  - Some designers of multilayer boards have resorted to running powerful routing software on very large in-house machines in batch mode.

  - CAD vendors are trying to respond to this problem.

    - An example is Lockheed's effort to offer the very powerful Automated Systems, Inc., PRANCE router package, in an interactive mode, as a module of CADAM.

    - Scientific Calculations, Inc.'s SCICARDS router is, in the view of most users, the best interactive router on the market today, and it is being continually improved.

- Meeting present and future CAD requirements to match the ever-growing complexity of printed and integrated circuits is the key driving force in the industry.

B. RESEARCH AND DEVELOPMENT EFFORTS IN SOFTWARE

- Present and future user needs of CAD systems for printed and integrated circuits cannot be met by conventional means of increasing computer capacity to match increasing circuit complexity.

- Even with improved cost/performance, the demands of time and computing power simply get out of hand and would far exceed any acceptable limits.

- The only solution is to "work smarter, not harder," which translates into breakthroughs in CAD/CAM software.

  - Very important research efforts in over 30 universities in the U.S. and similar efforts in England and Japan are focused on software R&D.

  - University research efforts are strongly supported by both industry and government because of the importance of solving the problem and keeping the U.S. printed and integrated circuit industry competitive.

- A good example of the research being done is a modified approach to design rule checking of VLSI circuits.

  - Checking circuit conformance with design rules after the circuit design has been tentatively completed can take days for present VLSI design.

    - This is clearly unacceptable performance, particularly looking ahead to future designs.

  - The approach that is the subject of current university research is to apply the principle of real time analysis to design rule checking.

    - If the research is successful, future design rule checks will be done in real time as the design progresses.

    - There will be no such thing as a subsequent run for design rule checking.

- Similar efforts are aimed at the other steps in the VLSI design, such as process:

- Circuit simulation.

- Functional and logic simulation.

- Topography verification (schematics).

- Testing.

- The various steps in production.

• An important overall conclusion is apparent.

  - The future of the electronic CAD industry will be determined by technology, with essential breakthroughs in software design stemming from the efforts of universities, industry, and government.

C. SYSTEMS PROCESSING CAPABILITY

• Present turnkey CAD systems generally lack sufficient processing capability.

  - This is due to the large demands previously discussed, particularly in design rule checking, simulation, and testing.

  - The result is that one user in a multiple workstation system can block out, or slow down, other users; a problem that can only get worse in the near term.

• Turnkey vendors are modifying their systems by increasing the graphics processor power to drive more workstations.

  - This approach has serious limitations in the longer term, given the magnitude of VLSI design requirements.

- Users of custom in-house systems are adding DEC VAX level graphics processors to help alleviate the problem; again, this has limitations.

- VLSI itself will provide the longer term solution by making it possible to economically place sufficient processing power at the workstation for the CAD system to operate in a true distributed data processing mode.

D. SCARCITY OF DESIGNERS

- U.S. government projections show that government, university, and industry requirements for computer science graduates needed for software development and CAD in all disciplines will exceed the supply by five times over the next five years.

- This scarcity is particularly limiting in the VLSI design field.

  - The elite group of designers tends to constrain industry growth, particularly as the designs increase in complexity.

  - They also tend to be mobile with respect to employment, which presents the industry with other problems.

  - The problem of scarcity must be solved to meet industry needs over the next five years.

- It is clear that a VLSI designer, or even a team of designers, can no longer deal with individual devices.

  - To quote from the Hewlett-Packard journal:

    . "By using the traditional paper doll approach of laying out individual polygons on mylar, digitizing and then assembling

these into an overall layout it would take, by some estimates, 60 years to lay out a chip with 100,000 devices."

- Finding an answer to these problems is the subject of intense university/industry research and development activity by such universities as the Massachusetts Institute of Technology, Carnegie Mellon, California Institute of Technology, Stanford, and the University of California at Berkeley, and by industry.

  - A common theme is emerging, namely structured design.

    - The goal is to structure the design process by splitting it into successively smaller pieces in such a way that it can be combined in a coherent fashion.

  - In many ways the structured design process is analogous to the top-down structured design approach used in designing complex software systems.

- A further goal of university/industry efforts is to establish means to train designers so as to greatly broaden the supply and circumvent the present shortage.

  - The goal is to take any promising college graduates with mathematic, scientific, or engineering backgrounds and train them as IC designers within a span of a few months.

  - This, of course, will be made possible by breakthroughs in CAD software and design methods.

- Improved design tools and methods for printed circuits must also be developed by university/industry efforts in order to handle the increased complexity stemming from placing the new IC devices on multilayer boards.

- Ten- to 20-layer boards are not uncommon in today's industry, which gives rise to very difficult placement and routing problems.

E. COMPETITION

- Competition is a key driving force in the industry, both among present U.S. vendors, and internationally, particularly from Japan.

  - Rapid advances in CAD technology are being achieved by Japanese and European efforts.

    - It is of interest to note that 25% of the papers presented at the recent ACM/IEEE Eighteenth Design Automation Conference were from Japan and Europe.

- Interesting management connotations stem from competitive forces:

  - CAD systems product life cycles are very short because of the rapid rate of technical obsolescence, and they must be replaced or fall behind competition.

  - Engineering employee relations factors are unique and very important.

  - The key to productivity is technology; management must realize that engineering has become a capital intensive function.

IV STATUS OF CAD/CAM

IV STATUS OF CAD/CAM

A. INSTALLED BASE AND PROJECTED PURCHASES

- Included in INPUT's definition of CAD/CAM systems is the use of interactive graphics.
  - This infers interactive computer assistance to a person who is working at a workstation or console where the station contains at least one graphics display terminal.
  - Scientific or engineering calculations that are done by means of batch or remote batch processing are not included in the definition.
  - The projections shown in this chapter reflect this definition.
- Types of CAD systems have been classified as follows:
  - Turnkey systems where the initial delivered system capability is fully operable and usable in the customer environment, as typified by offerings from Computervision, Applicon, and Calma.

- In-house equipment where the customers/users integrate individually purchased hardware components into existing CAD/CAM systems, or CAD/CAM systems developed by their own organizations (custom built systems).

- Remote computing services (RCS) offerings in the CAD/CAM graphics markets.

- Software products (CAD/CAM graphics software offerings).

- The types of CAD systems respondents are using, broken down in the above categories, are shown in Exhibit IV-1.

  - Many users of in-house installations of CAD/CAM also use turnkey systems; in fact, almost all the large IC vendors do.

  - Use of RCS for CAD/CAM is small in comparison, because of the expense involved in communications links required for interactive graphics.

- Some of the characteristics of the turnkey systems' installed base are listed below.

  - By the end of 1980 the electronics industry segment had approximately 6,500 workstations installed in CAD/CAM turnkey systems worldwide. In the U.S. there were approximately 4,400 installed by the same date.

  - The number of workstations per system in the U.S. averages about four; i.e., there were about 1,100 systems installed in that sector.

  - INPUT estimates that revenues derived from the electronic CAD/CAM turnkey system installed base has been $440 million (or about $400,000 per system) since inception.

EXHIBIT IV-1

TYPES OF CAD SYSTEMS CURRENTLY IN USE BY RESPONDENTS

SYSTEM/SERVICE/PRODUCT	PERCENT USING
• Turnkey Systems	89%
• Software Products	38
• In-House Mainframe and Own Custom Systems	13
• Remote Computing Services	16

NOTE: SOME USERS UTILIZE SEVERAL OF THE ABOVE, THEREFORE PERCENTAGES TOTAL TO MORE THAN 100%

- Revenues of CAD/CAM turnkey systems in the electronics industry segment in 1980 are estimated to have been $165 million.

    - During 1980, 25% of the total installed base was sold; in other words, only three times as many systems were sold during all years prior to 1980 as were sold in that year, a clear measure of the rapid growth rate of the turnkey systems market.

- The market for electronic CAD/CAM systems, software, and services in 1980 is estimated at $243 million, and is forecast to grow at a compounded rate of 32% per year, reaching $1.3 billion in 1986.

    - Market projections are shown in Exhibits IV-2 and IV-3.

    - Growth is attributable to the fact that next generation, state-of-the-art CAD/CAM systems are not discretionary in the printed and integrated circuit industry; they are essential for survival in a competitive world market.

- The two dominant modes of delivery for CAD/CAM systems are turnkey and in-house (customer) equipment.

    - The electronic market today is dominated (almost two-thirds) by turnkey systems offered by established turnkey vendors.

    - In the future, INPUT predicts, in-house equipment as well as software sales will rapidly overtake the turnkey segment of the electronic marketplace, growing at a combined AAGR of 49%, and accounting for 56% of the market in 1986.

        - This rapid growth will be directly attributable to massive in-house development programs by the larger companies aimed at developing advanced function systems which will not be made available from the turnkey vendors.

EXHIBIT IV-2

PROJECTED GROWTH OF ELECTRONIC CAD/CAM
SALES IN THE UNITED STATES

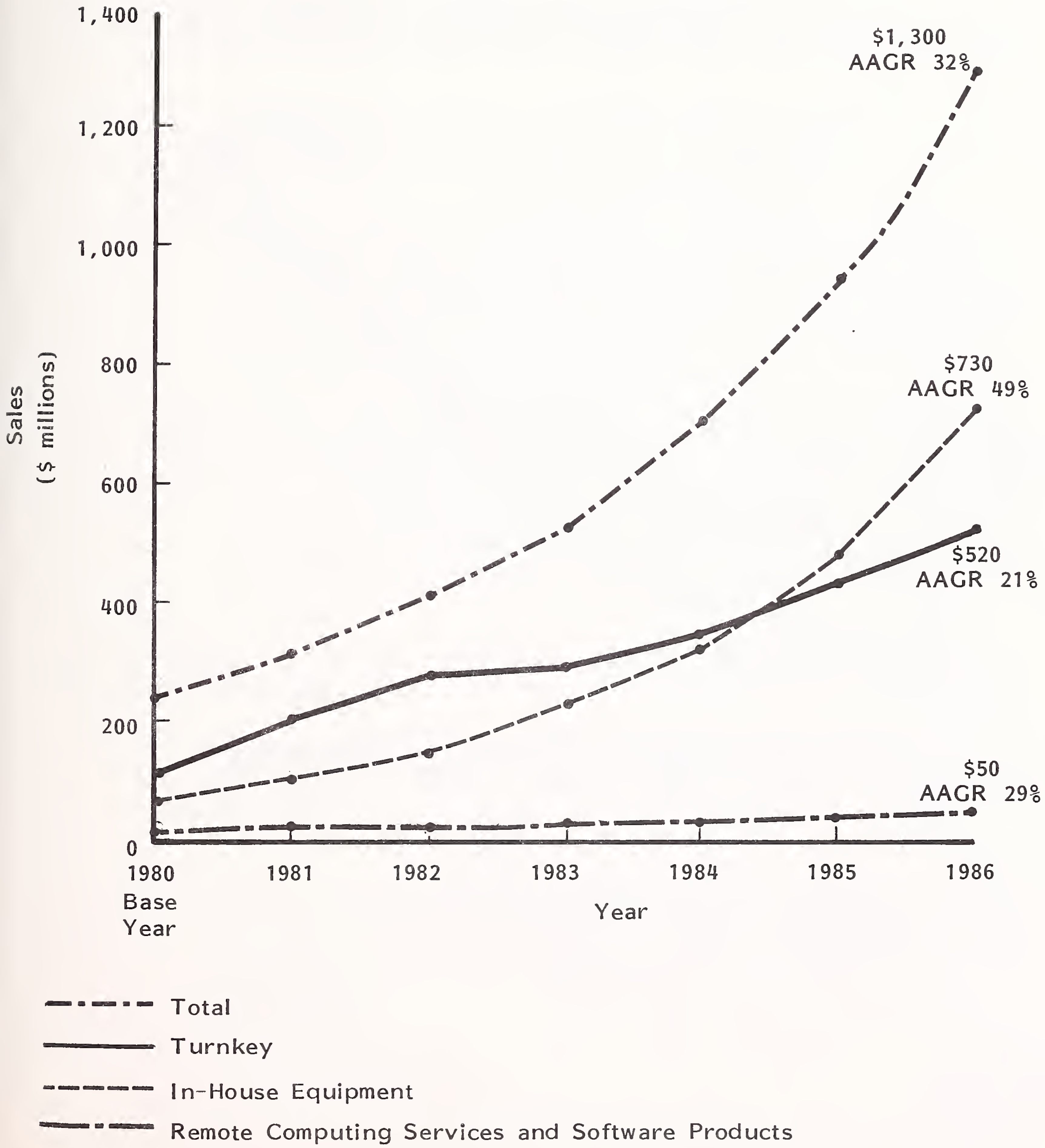
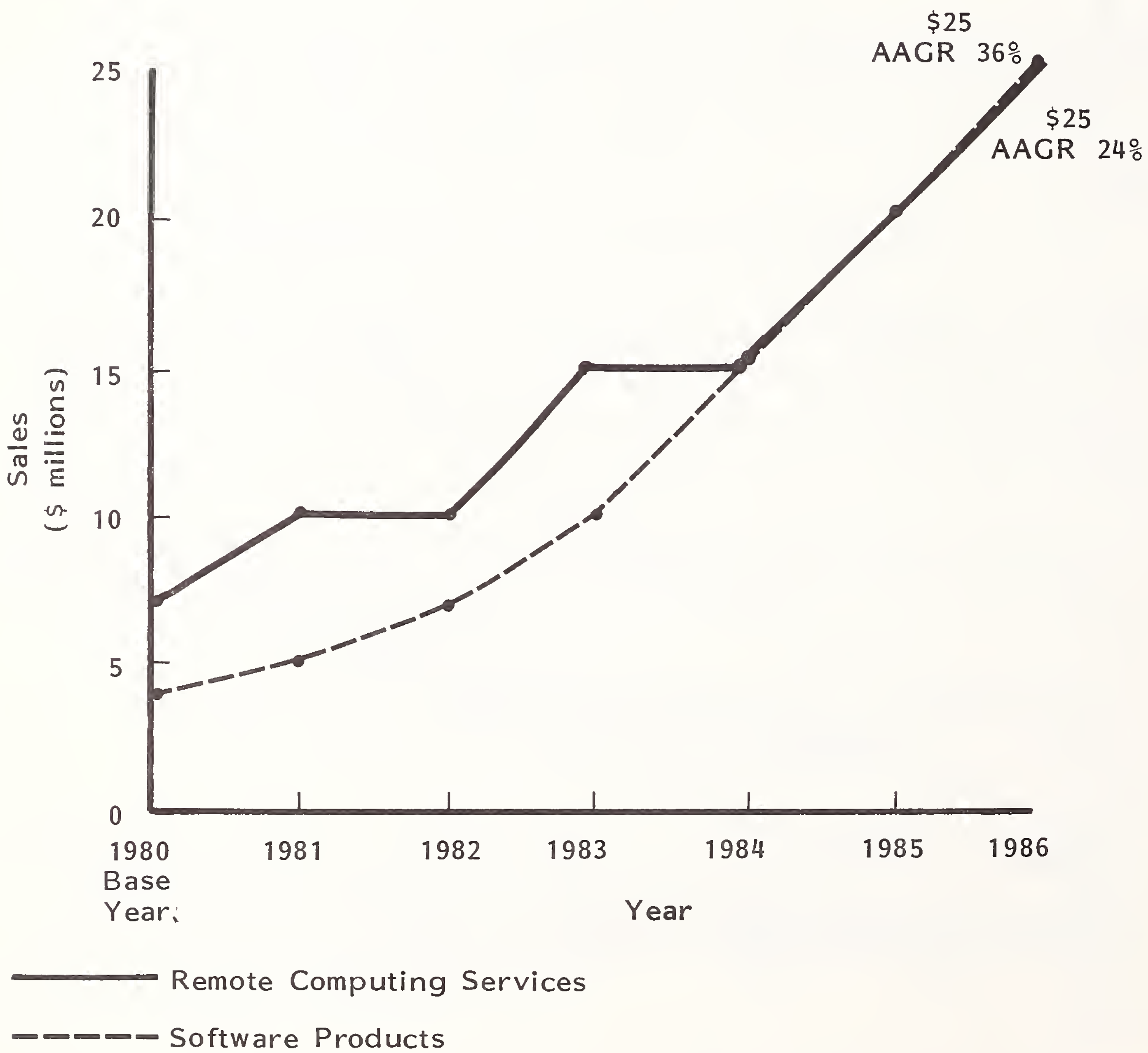


EXHIBIT IV-3

PROJECTED GROWTH OF ELECTRONIC CAD/CAM
REMOTE COMPUTING SERVICES AND SOFTWARE PRODUCTS SALES



- Use of remote computing services is small by comparison because of limitations imposed by the large communications requirements for interactive graphics.

B. USER ACTIVITIES

- Classically, interactive graphics workstations have been located in a central design facility, and they still are today, as shown in Exhibit IV-4.

  - This is due primarily to system constraints where processing power is concentrated centrally in the graphics processor, and economics constrain the proliferation of graphic workstations co-located with design groups.

- INPUT projects that by 1986 the situation will be reversed and the processing will be mostly distributed, with workstations placed at designer locations.

  - This will be made possible by improvements in the cost/performance of the equipment.

- Specialist CAD operators are presently the primary operators of CAD systems, as shown in Exhibit IV-5.

  - Seventy-five percent of engineers do not generally use the CAD system directly.

  - INPUT projects that this situation will change by 1986, and engineers will be heavy users of the system because of convenience of the workstation location and improvements in the software which will facilitate use.

EXHIBIT IV-4

LOCATION OF WORKSTATIONS

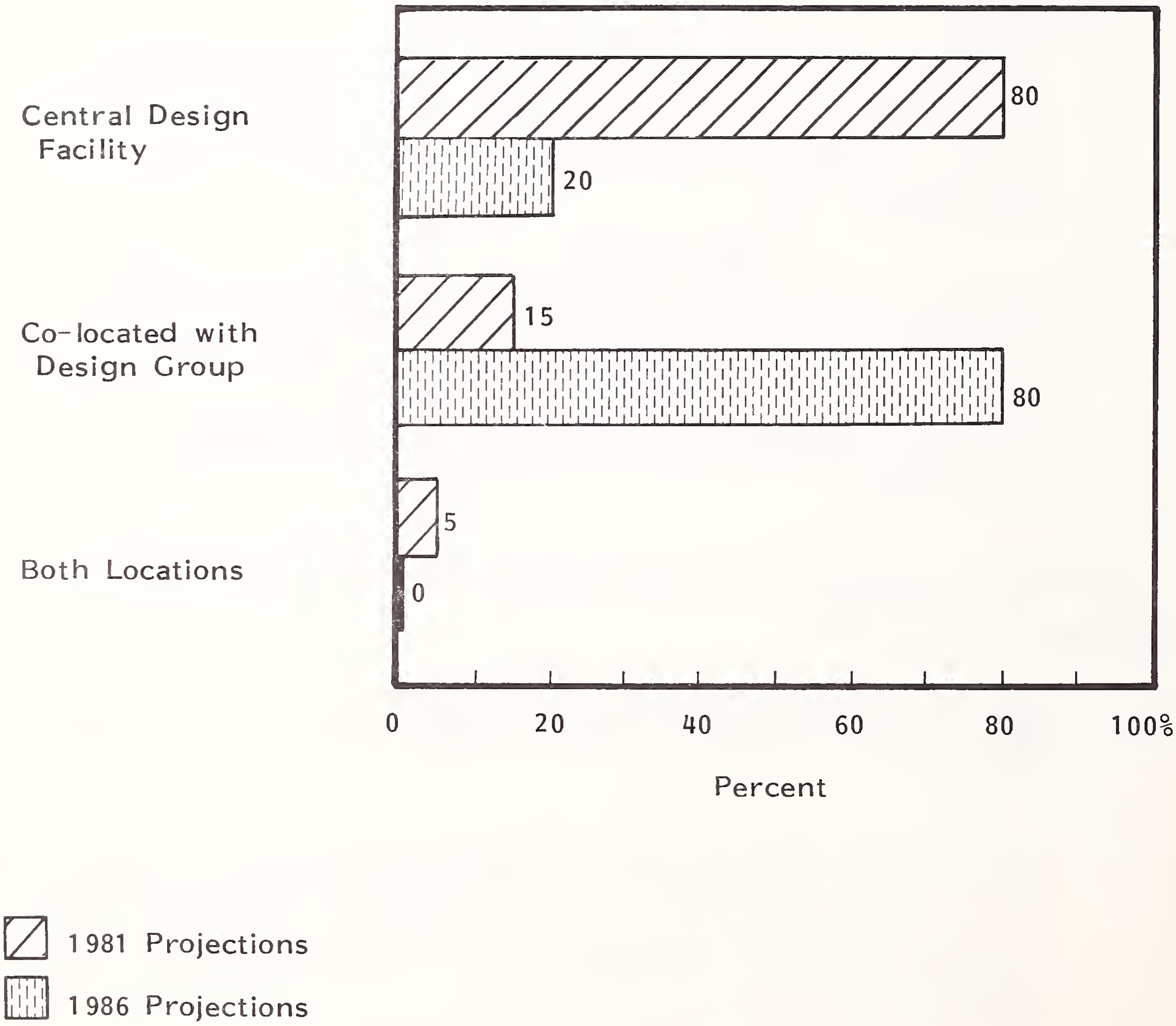
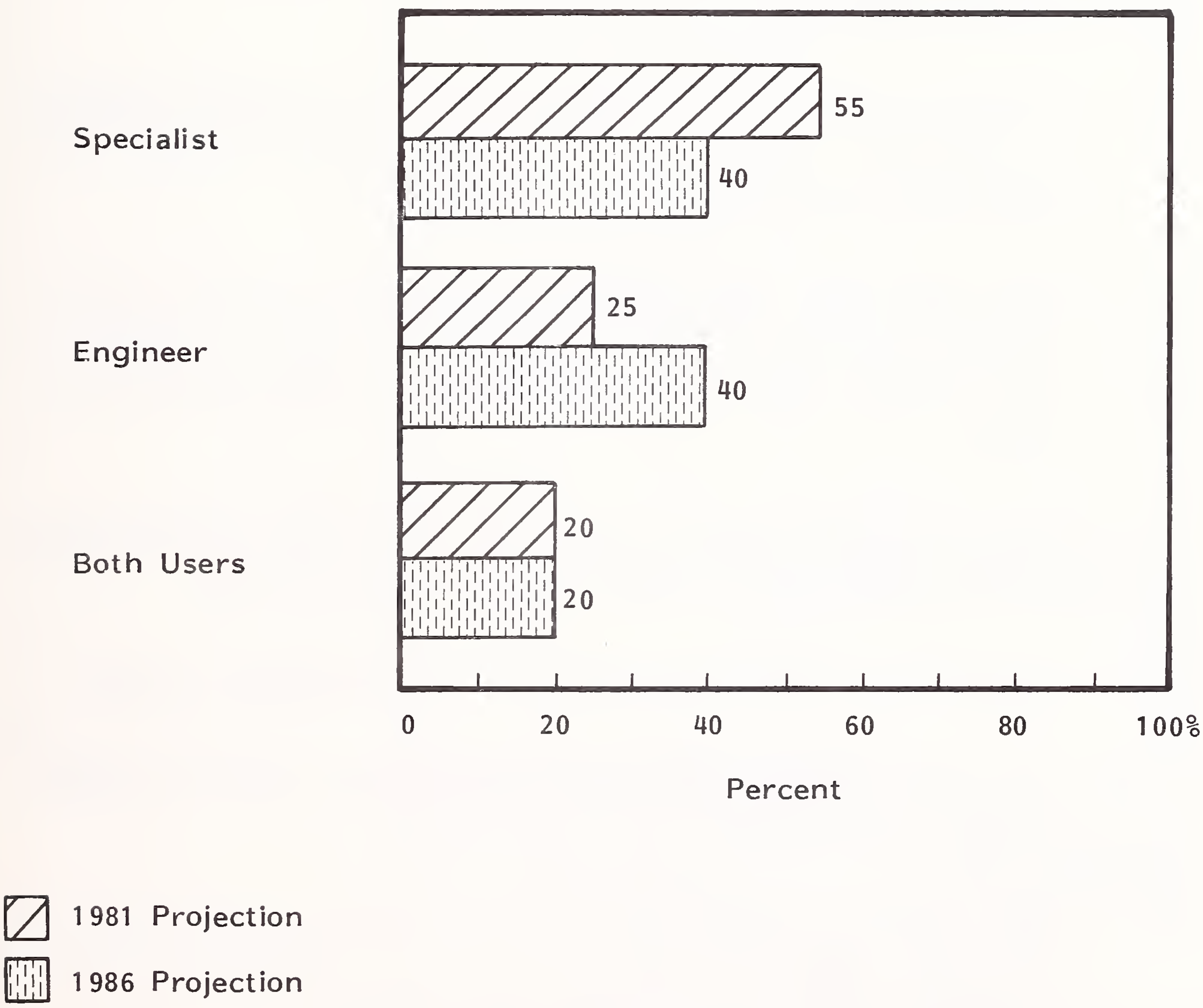


EXHIBIT IV-5

OPERATORS OF CAD SYSTEMS



- The stage is set to broaden both the location and use of CAD systems over the next five years, which will solve many of the present design and fabrication constraints.

- Currently, the analysis and processor intensive functions are shared almost equally between the in-house mainframe and the graphics processor, as shown in Exhibit IV-6.

  - The distinction is somewhat blurred because the turnkey systems are often configured in the overall system design, including interfacing with the host computer.

  - There is not yet evidence of significant distributed data processing, but by 1986 INPUT projects that DDP (i.e., the satellite processors) will handle most of the processor intensive functions.

  - One would expect that the reported 10% of the processing done by remote computing services does not involve interactive graphics, but rather "Cyber" type remote batch scientific and engineering calculations.

- The "structured design approach" for computer aided design of VLSI circuits, so vital for the design of VLSI circuits, is already in widespread use.

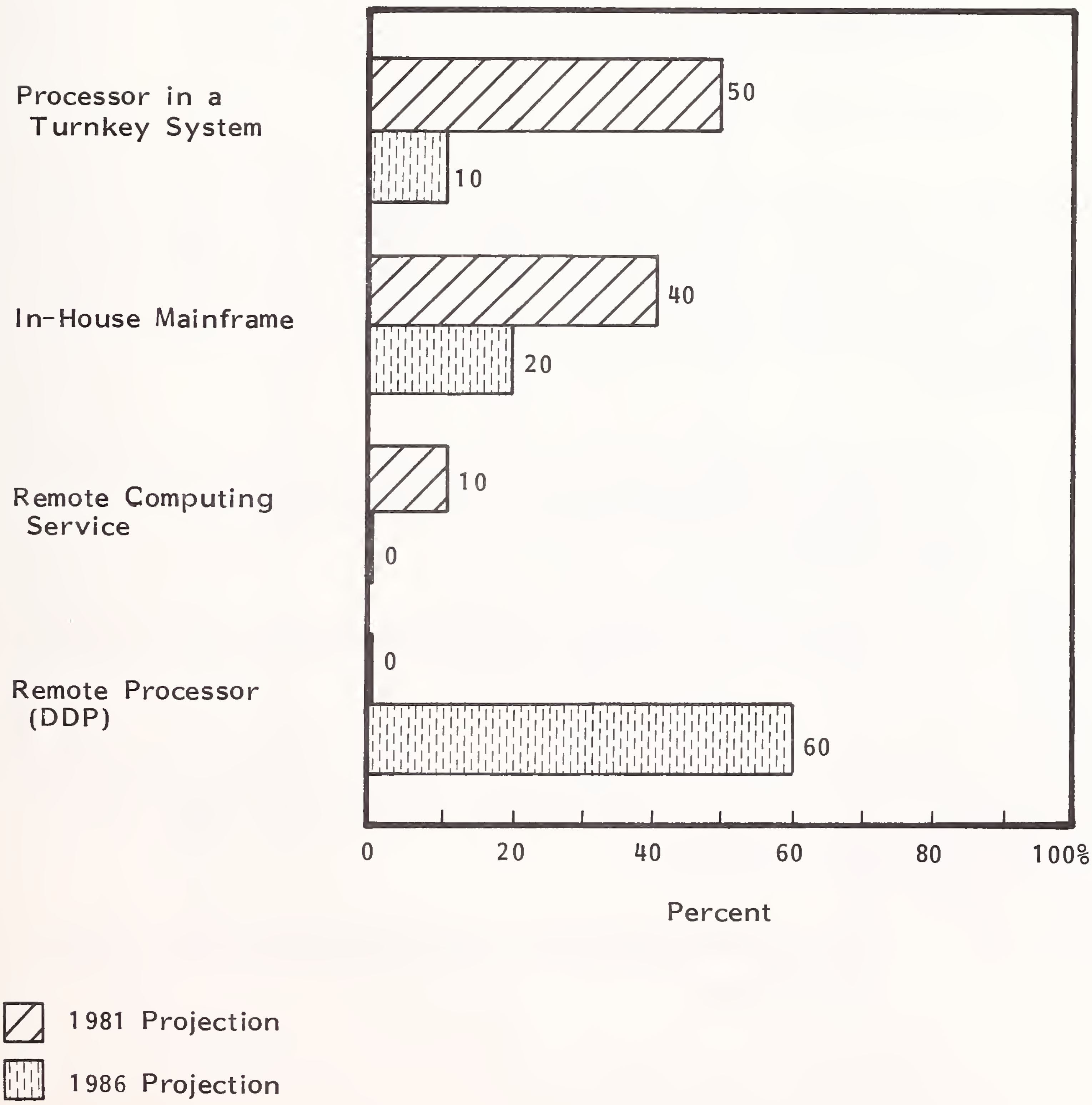
  - Over 80% of IC respondents currently use structured design methods.

- Using this top-down approach, designers are able to build up large circuits out of increasingly complex cells.

  - They start, for example, with a set of primitive elements such as transistors, diodes, and resistors to build a gate, a set of gates to build a register, and so on, in the building block method.

EXHIBIT IV-6

WHERE ANALYSIS AND PROCESSOR INTENSIVE FUNCTIONS ARE PERFORMED



- Ratings of the four most favored methodologies for IC design are shown as follows (10 is most favored and 1 is least favored):

Methodology	Average Rating
Gate Array (Uncommitted Logic Arrays)	6.5
Standard Cells	6.5
Custom Design (Handcrafted)	6.3
Symbolic Design	5.6

- Ratings of the adequacy of individual features of present and future CAD/CAM systems for integrated circuit design indicate a considerable need for further research and development beyond today's systems and a very guarded optimism that the needs will be met by 1986; results are shown in Exhibit IV-7.

  - A particular weakness in circuit simulation, functional and logic simulation, and testing (the least developed feature) bears out previous INPUT research results.

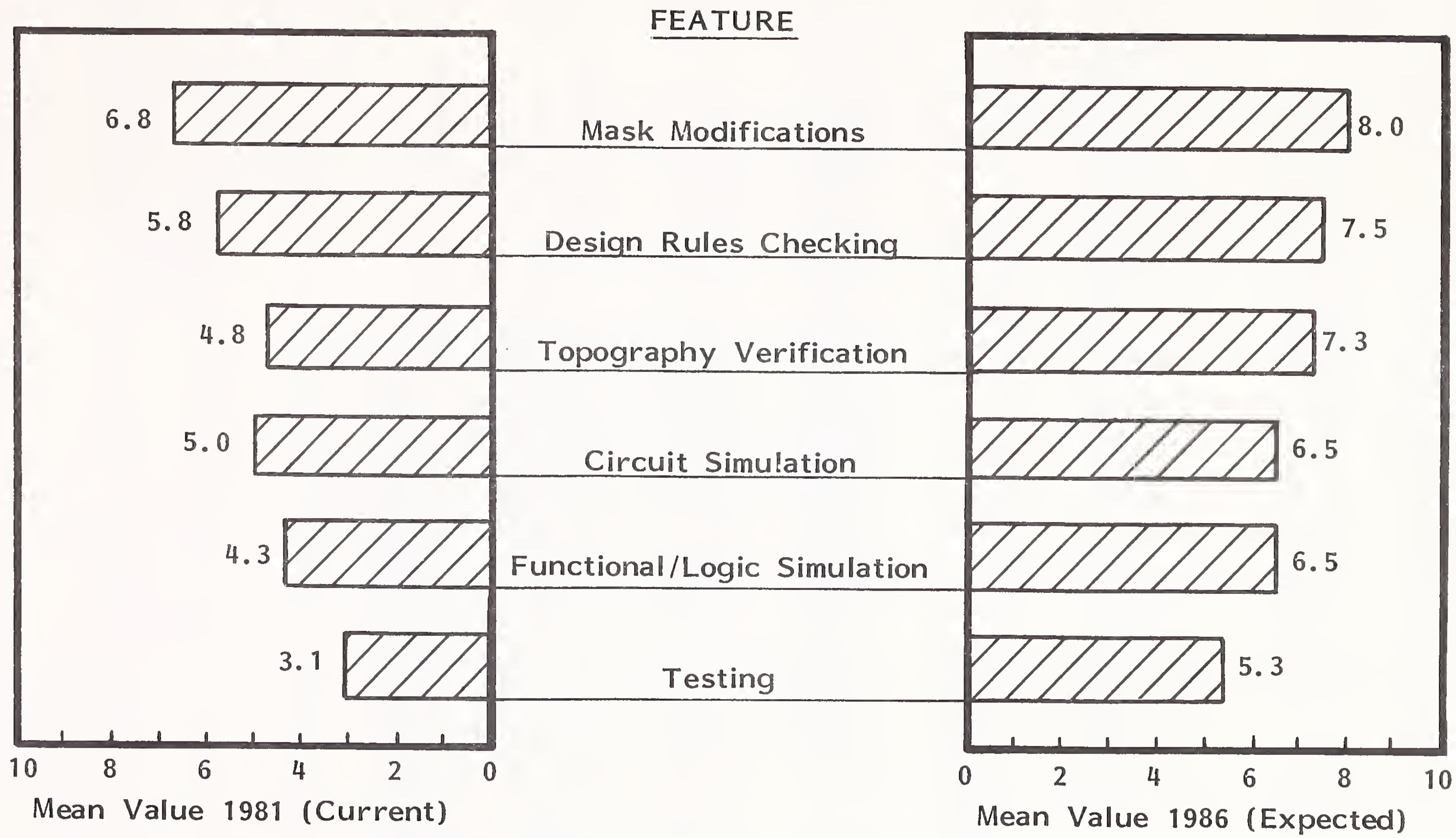
    - Testing in particular is almost all done manually and is today's crisis.

  - The problem is that even though technological advances in CAD/CAM systems are achieved, circuit complexity increases so rapidly that one never seems to catch up.

    - The "light at the end of the tunnel" is not yet visible for VLSI design systems.

EXHIBIT IV-7

ADEQUACY OF INDIVIDUAL FEATURES OF CAD/CAM SYSTEMS FOR INTEGRATED CIRCUITS DESIGN, 1981 AND EXPECTED IN 1986



Rating Scale:
1 = Completely Inadequate
10 = Totally Fulfills Need

*SEE APPENDIX B FOR DETAIL

- CAD/CAM systems come much closer to meeting design requirements for printed circuit design than for integrated circuits.

  - The feature most in need of improvement is automatic routing and placement of multilayer boards, as shown in Exhibit IV-8.

    . Automatic routing of multilayer boards is a very complex problem, and one that is receiving a great deal of research and development attention from universities and industry.

- Libraries for PCB design are an important CAD feature for complex boards, as shown in Exhibit IV-9.

  - Such libraries are growing rapidly with schematic symbols, component parts, and component outline libraries considered most important.

- Although it is a relatively older technology it seems that there will always be a use for wire-wrap methods.

  - Wire wrap is used in some instances for breadboard designs of printed circuit boards in order to minimize expense.

  - Wire wrap is also used in some instances when only a one of a kind board is desired, again to save costs.

- Key features of CAD systems for wire-wrap circuits include:

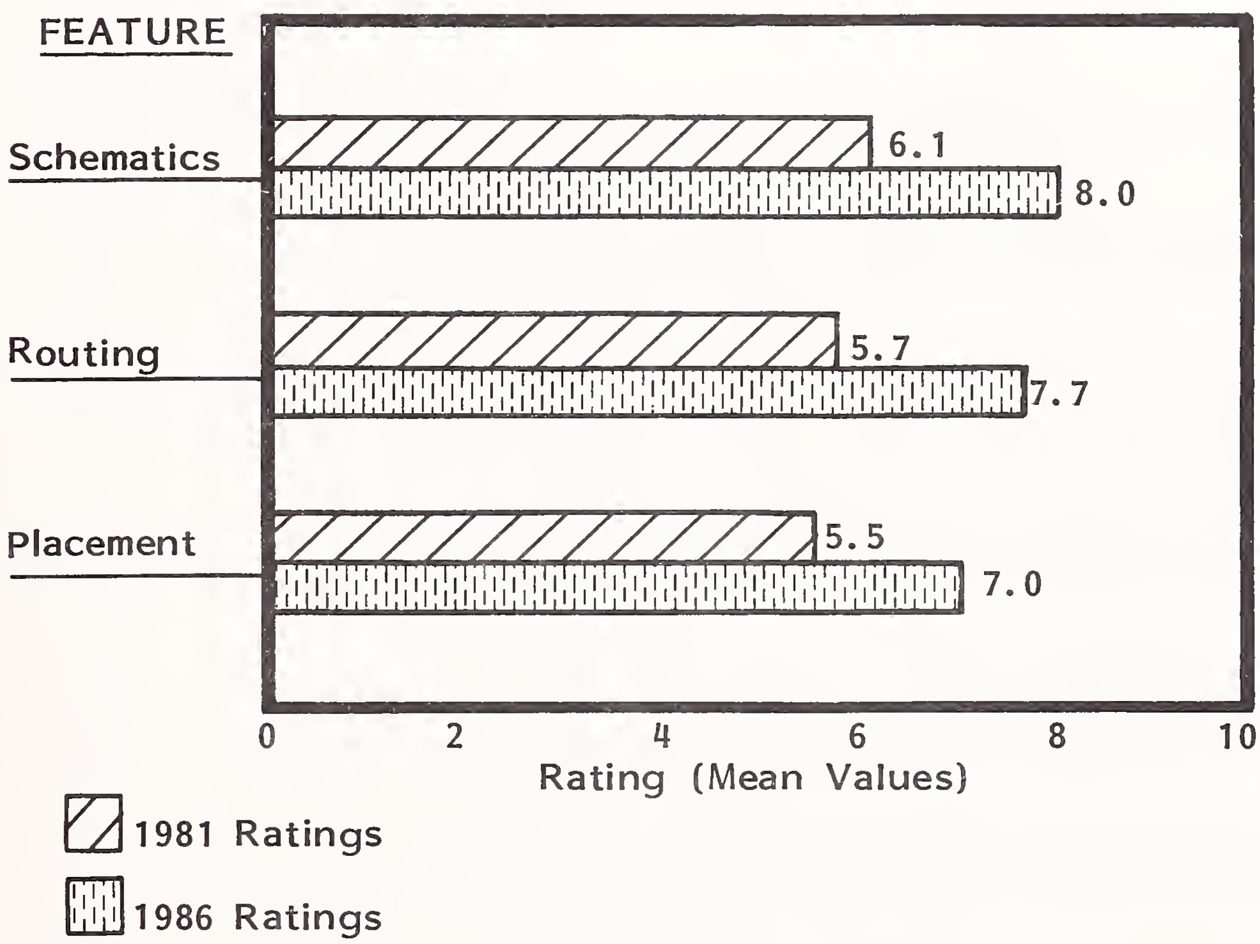
  - Using net list as a basis for wire-wraps and multiwire design.

  - Minimizing wire changes in design update while maintaining data and design integrity.

  - Utilities to produce properly formatted N/C, wirewrap, and multitape in standard format.

EXHIBIT IV-8

ADEQUACY OF INDIVIDUAL FEATURES OF CAD/CAM SYSTEMS FOR PRINTED CIRCUIT BOARD DESIGN, 1981 AND EXPECTED IN 1986



Rating Scale:
1 = Completely Inadequate
10 = Totally Fulfills Needs
* SEE DETAIL APPENDIX B

EXHIBIT IV-9

IMPORTANCE OF LIBRARIES
FOR PRINTED CIRCUIT BOARD DESIGN

FEATURE	RATING	
	1981	1986
Schematic Symbol Library	8.5	9.1
Component Parts Library	8.1	8.9
Component Outline Library	7.6	8.4
Hybrid Chip Library	6.1	8.0
Circuit and Logic Simulation Library	4.9	8.0
Mechanical Shape Library	6.1	7.6

1 = NOT REQUIRED
10 = CRITICALLY IMPORTANT

- Users groups are an important means of communications for both users and vendors of CAD/CAM systems.

  - Ninety percent of user respondents belong to user groups.

  - The groups are mostly formed around specific vendors, like:

    - ASCUS - Association of Calma Users.

    - DECUS - Digital Equipment Corporation.

    - SHARE - I.B.M.

    - CUE - CADAM Users Exchange - Lockheed.

    - MIDWEST - Computervision.

  - The primary purposes of users groups are:

    - A user forum for the exchange of ideas, experiences, and solutions to mutual problems.

    - A means for users to influence future vendor developments, particularly new software releases.

    - An aid to users in implementing new vendor software releases, which are usually fraught with problems.

  - There is an acknowledged gap between user requirements and turnkey vendor offerings.

    - This is due, in part, to a communications problem and turnkey vendors find the user group an effective mechanism for helping to decide on future product development.

- Users rated the effectiveness of user groups 7.1 on a scale of 1 to 10, which speaks well for the value of the groups.

- The most important governmental program relating to integrated circuit design is the VHSIC - Very High Speed Integrated Circuit program.

  - The program is funded by the Department of Defense to stimulate IC design and ultimately regain superiority over foreign technology in defense.

  - The program is well known to the IC industry, with over 75% of IC respondents being aware of the program.

  - Over one half of the effort will focus on systems problems, like:

    - Design architecture.

    - Software.

    - Testing.

  - The other half of the effort will focus on order-of-magnitude improvements in IC design.

    - The goal of the IC effort is to reduce chip design rules from the present 3 microns to 1.25 microns, and ultimately to the submicron range.

    - At the same time to increase throughput by a factor of ten.

  - If these goals are reached, it is beyond present imagination to anticipate the dramatic effect such circuits will have, and the enormous requirements of CAD/CAM systems to design and manufacture them.

- There are many contracted efforts going on comprised of teams of systems contractors and IC manufacturers.

- Projected time scales are post-1986.

C. VENDOR ACTIVITIES

- The three major turnkey CAD/CAM vendors to the printed and integrated circuit industry are Computervision, Applicon, and Calma; their respective 1980 worldwide market shares are shown in Exhibit IV-10.

  - All three vendors have about the same total number of systems installed.

  - Calma and Applicon are also close to one another in 1980 revenues.

    . Calma, who concentrated on gaining entry to the mechanical market in 1980, has slipped somewhat behind its previous position.

    . The effects of being acquired by GE also are being felt by Calma, with the final outcome still inconclusive.

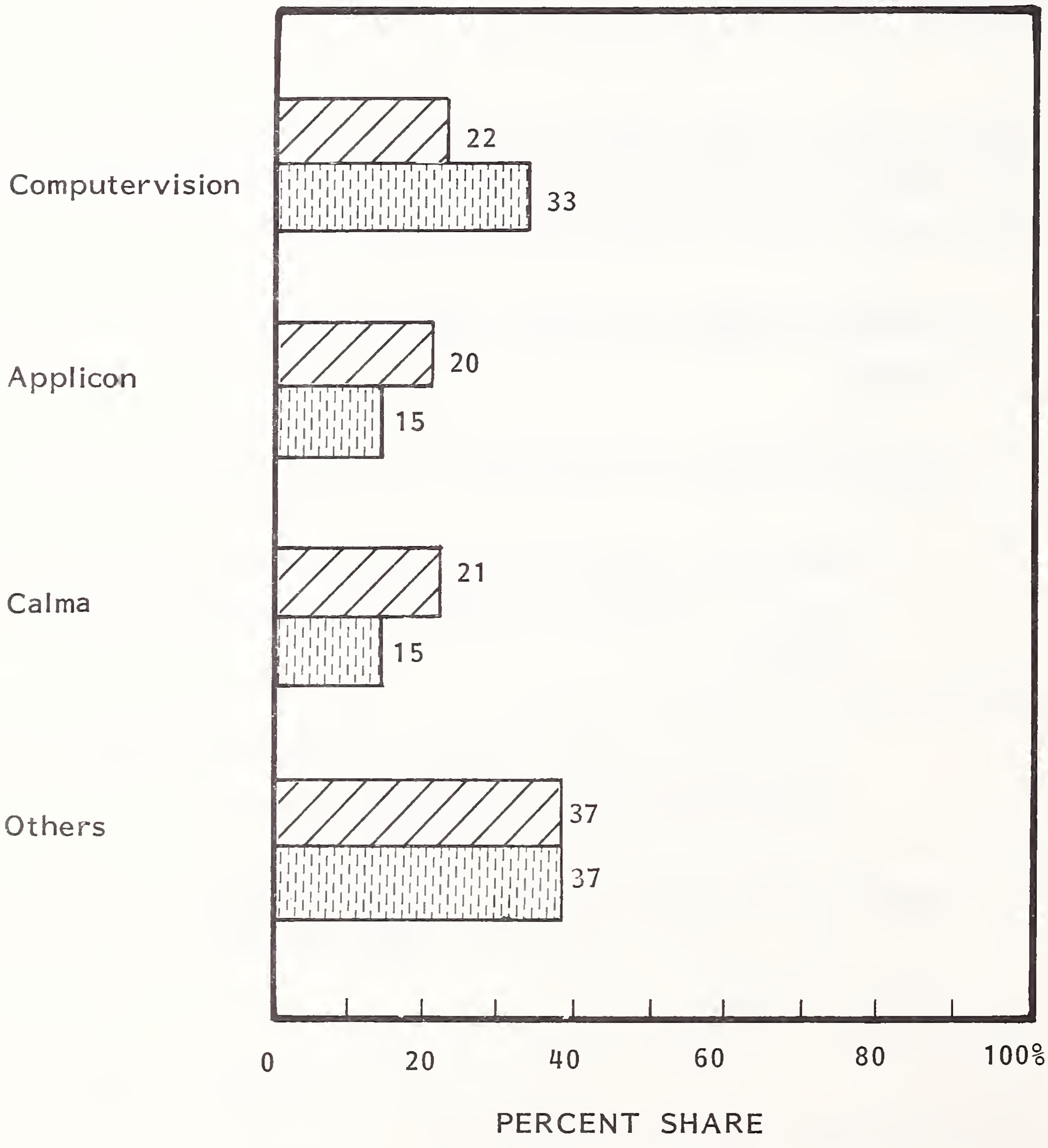
  - Computervision had much greater 1980 revenues from the electronic CAD sector than the other two vendors with the same number of systems installed.

- Ratings of the ability of the integrated circuits CAD system vendors to meet overall user needs are shown in Exhibit IV-11.

  - Calma is clearly the preferred vendor with respect to the suitability of its product to meet design requirements.

EXHIBIT IV-10

VENDOR SHARES OF ELECTRONIC CAD TURNKEY MARKET

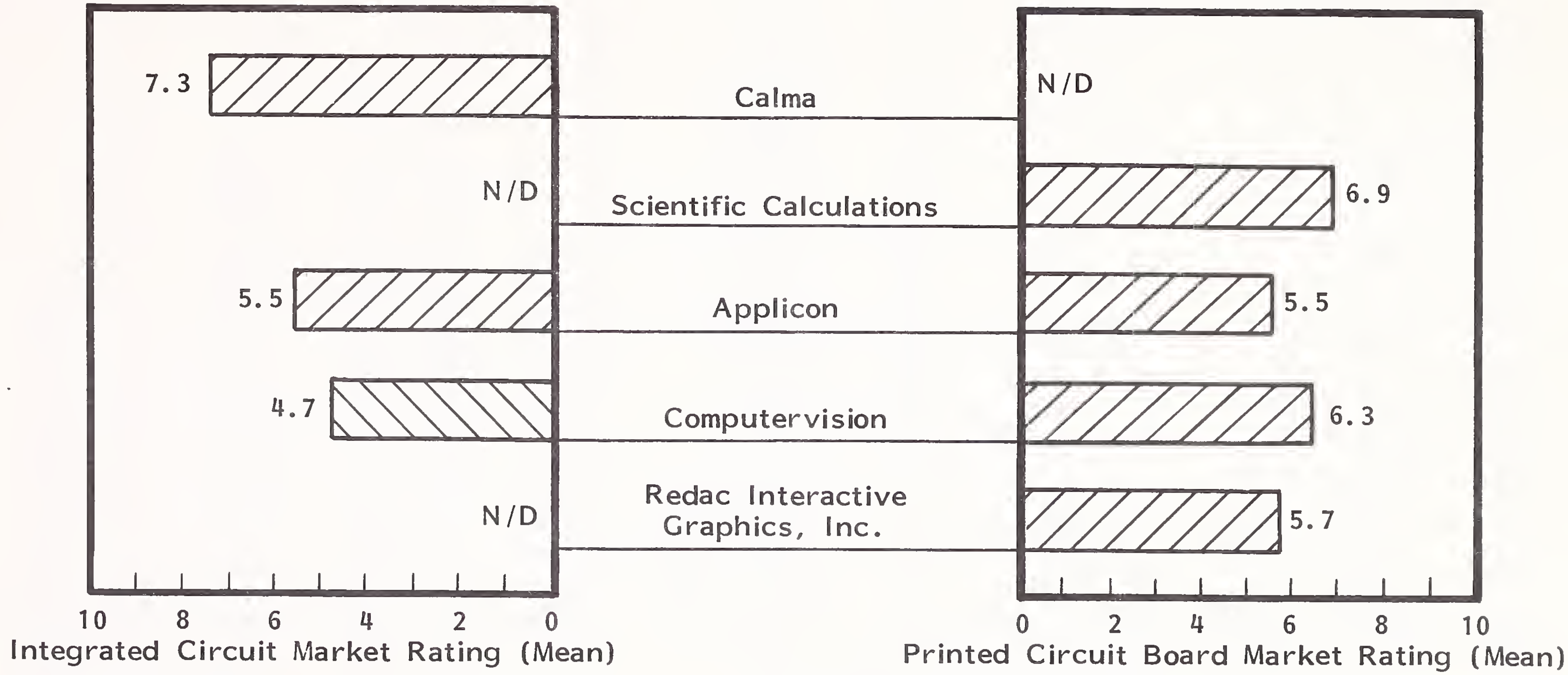


= Percent by Total number of systems installed at Year End 1980

= Percent by 1980 Revenue, (Total in 1980 $165 million)

EXHIBIT IV-11

ABILITY OF CAD VENDORS TO MEET OVERALL USER NEEDS



Rating Scale:
1 = Completely Inadequate
10 = Totally Fulfills Needs
N/D= No Data

* SEE APPENDIX B FOR DETAIL

- The GDS-I and GDS-II systems are widely used.

- With GE backing it has the means to become the dominant turnkey vendor for VLSI if it chooses to be.

- Applicon is rated average, which indicates that it falls short of user needs for VLSI designs.

- Computervision does not focus on this market.

- Ratings of the ability of the PCB CAD system vendors to meet overall user needs are also shown in Exhibit IV-11.

  - SCICARDS from Scientific Calculations, Inc. is the preferred PCB vendor.

    - Most observers in the industry agree with this, and previous INPUT research established SCICARDS as the top vendor for PCB design.

    - It has excellent router, placement, and schematics packages and the product is well maintained.

- Although not mentioned by respondents, Gerber Scientific is now directing its new application development efforts toward the electronic applications area in general, and the printed circuit board field in particular.

  - The Gerber PC 800 system is designed to address the needs of large-scale integration (LSI) and multilayer PCBs.

- Evaluating the turnkey vendors on a relative basis is one thing, but on an absolute basis of their meeting the very demanding CAD/CAM needs of printed and integrated circuits is another.

- In this context, all the turnkey vendors fall far short of meeting industry needs over the next five years.

- Software is the key and the turnkey vendors do not appear to be taking advantage of the university research at such institutions as the Massachusetts Institute of Technology, California Institute of Technology, University of California at Berkeley, and Stanford.

- Companies like Hewlett-Packard, Xerox, Texas Instruments, Intel, and National Semiconductor, with their custom design systems, are leading the way by sponsoring university research and applying it.

• It is too soon to know exactly how the CAD/CAM needs of the industry will be met, neither is it clear that the turnkey vendors will play a vital role.

  - INPUT forecasts, however, that the IC industry itself will find solutions to the enormous problems of complexity with custom designed systems.

V ECONOMIC ISSUES

V ECONOMIC ISSUES

A. JUSTIFICATIONS AND BENEFITS

- The recurrent theme throughout this study is that the CAD/CAM industry is technology driven.

  - This applies in even a broader sense to the entire subject of productivity, the key word that could well be an alternate title for this chapter.

- Some interesting evolutions were identified in a recent study of the Brookings Institute, which are summarized in Exhibit V-1.

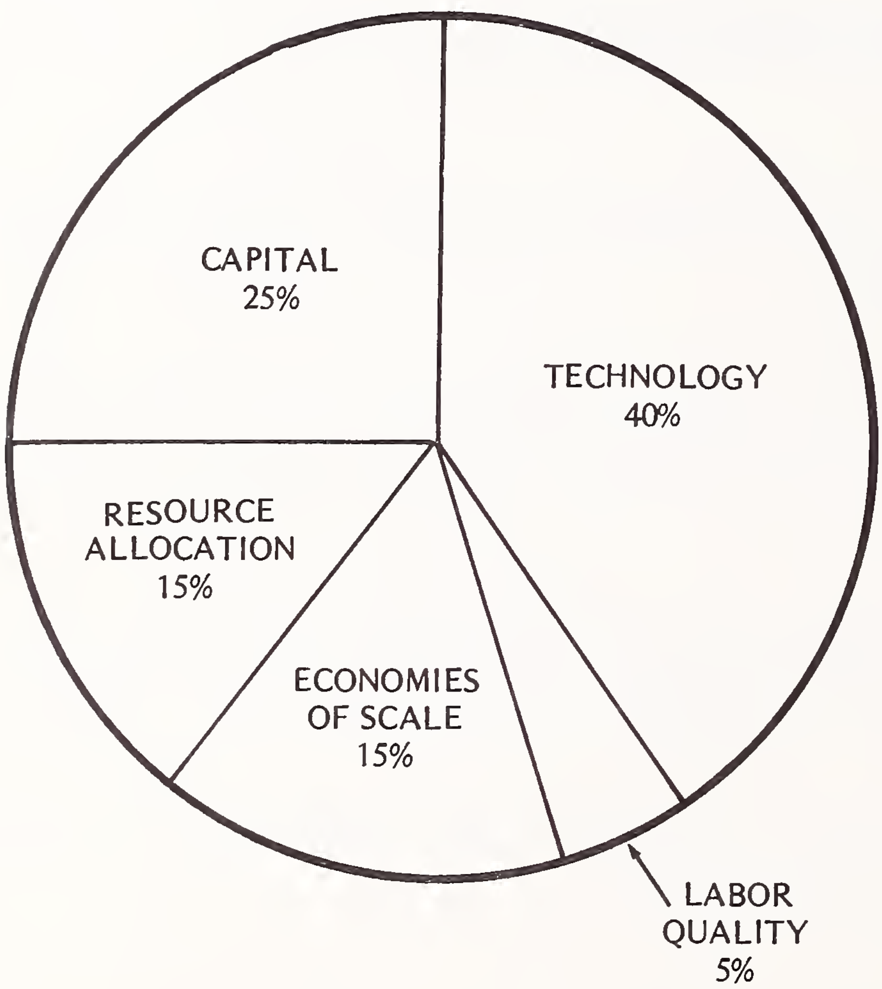
  - In the past, capital and labor quality were the dominant factors affecting productivity.

  - Today technology, almost all of it computer related in some manner, is by far the dominant force for achieving gains in productivity.

- Within the broad context of productivity, the key issues in cost justification of CAD/CAM systems were examined in this study; results are shown in Exhibit V-2.

EXHIBIT V-1

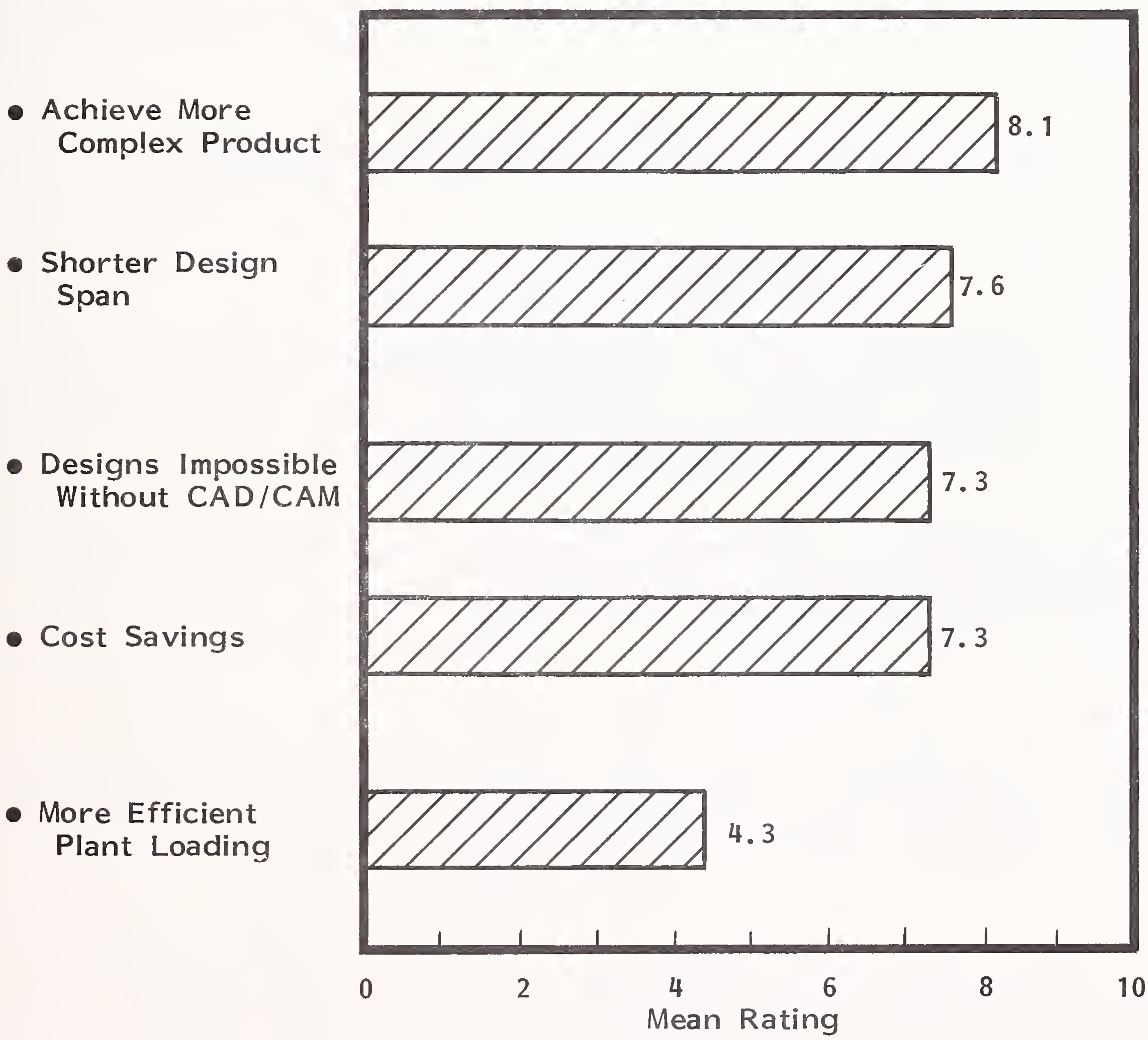
FACTORS AFFECTING PRODUCTIVITY



SOURCE: BROOKINGS INSTITUTE

EXHIBIT V-2

IMPORTANCE OF KEY ISSUES IN
COST JUSTIFICATION OF CAD/CAM SYSTEMS



Rating Scale:
1 = No Importance
10 = Vital Importance

* SEE APPENDIX B FOR DETAIL

- The basic justification for CAD/CAM systems in the printed and integrated circuit industry is that it is the only approach.

  - Designs would not be feasible without CAD/CAM, and as a practical matter the industry could not exist in its present form.

  - Just knowing that a CAD/CAM system is essential, however, does not help much in selecting and justifying a specific system, so the other key factors in justification must be considered.

- The need to constantly increase product complexity means growing reliance on CAD/CAM.

  - The first criterion for justification is design quality/complexity.

  - It is essential to being competitive.

  - Putting a value on such product characteristics as capability, reliability, productibility, maintainability, etc. may be difficult, but obviously they are most important considerations.

- Shortening design or project time spans is by far the most highly leveraged issue for cost justification.

  - Every business knows that time is money.

  - Shortened design times mean less labor expense and less overall expense.

    - Any large project that can be materially reduced in time will result in very large savings.

- The most important benefit attributable to shortened design spans is not cost savings at all, but rather increased sales due to lengthened product life cycle, as shown in Exhibit V-3.

  . Any product, independent of its existence, has a potential demand curve with a finite life.

  . If CAD/CAM systems vendors allow products to be brought to market earlier, the additional sales due to lengthened product life cycle can be very large compared to the expense of the CAD/CAM system and can justify systems costs many times over.

• Productivity due to direct cost benefits is a lesser basis for justification than the other areas discussed.

- However, to some extent reduced design labor is easier to quantify, and if a case can be made to show that CAD/CAM produces cost savings due to labor displacement then, considering the other more important factors, cost justification will be impressive indeed.

- Another way to measure direct cost benefits is to look at the amount of work accomplished per unit of expense, like the number of designs per unit of labor expense.

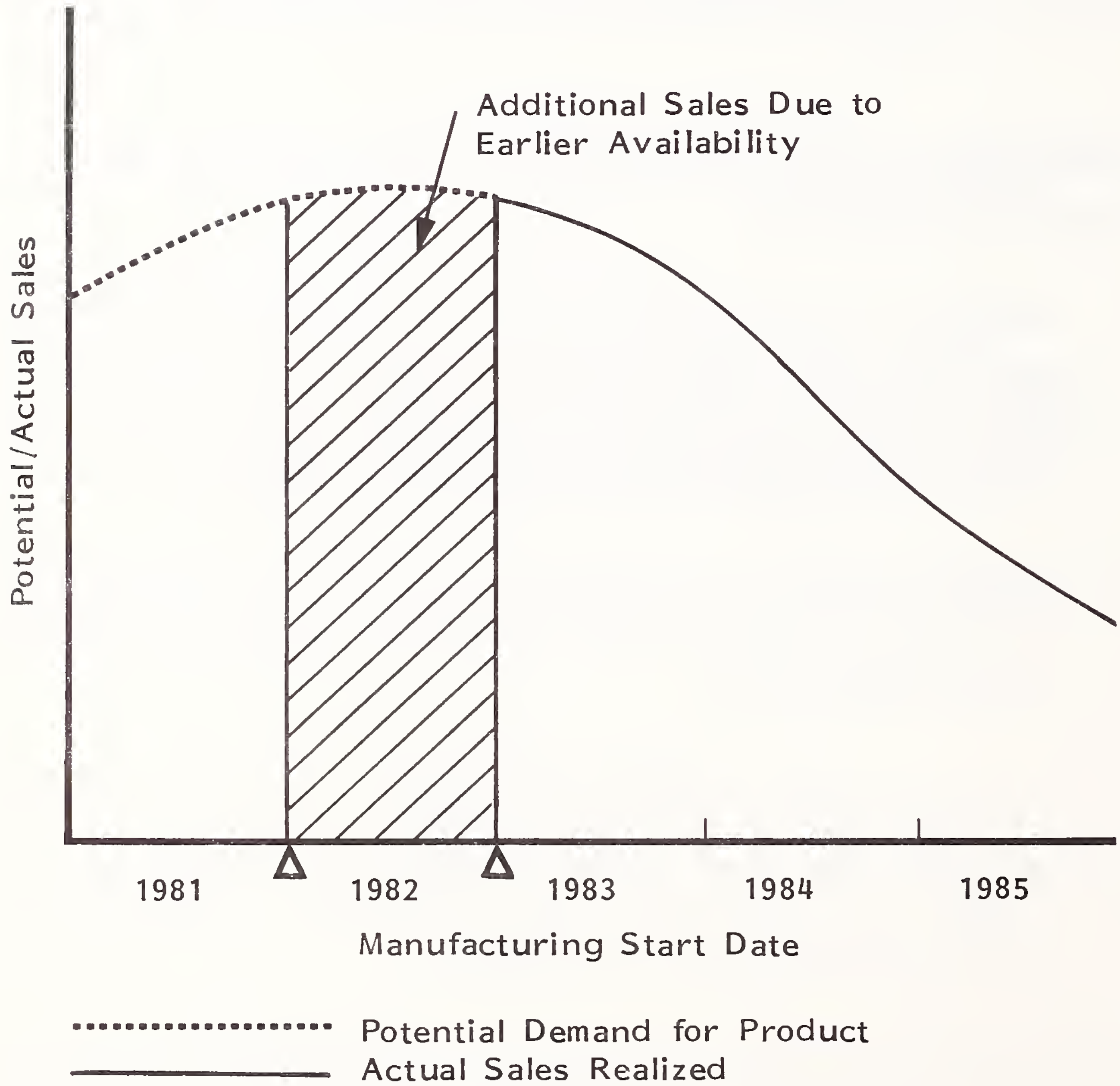
- Most users feel that productivity gains due to direct cost benefits will run from five to ten times greater for CAD systems over manual systems, but it all depends on the comparison: VLSI gains compared to manual methods would be tremendous.

• CAD/CAM systems can be used to plan and schedule manufacturing activities to achieve more efficient plant loading, resulting in overall cost savings.

- Ratings of the value of this benefit were very scattered, which might lead to the conclusion that it is not an important cost justification for CAD/CAM systems.

EXHIBIT V-3

GAINS IN PRODUCT LIFE CYCLE
DUE TO SHORTENED DESIGN SPANS



- The subject relates closely to CAD/CAM integration and common data bases, an area of enormous potential for productivity improvements but also an area where very little has been accomplished, as will be discussed in subsequent chapters.

- The scattered ratings of the importance of better plant utilization indicates that users do not fully appreciate the potential of CAD/CAM in this area.

• Typical user responses to the question of how productivity gains associated with CAD/CAM implementation can be measured are as follows:

  - "Shorter design span is by far the most important."

  - "More output for a fixed budget."

  - "Real success is to achieve better turnaround time."

  - "Very difficult to measure because design is a constantly moving target."

  - "In NASA spacecraft, if schedule could be shortened by one week, it would be worth an incredible amount of money."

  - "Have not reduced labor, but other benefits are much more important."

  - "Getting the design right the first time means less interaction, which translates into large cost savings."

  - "There are more design options in CAD."

  - "Achieve higher quality design with less skilled people."

- The extent to which CAD/CAM installations meet user expectations at the time of purchase is shown in Exhibit V-4.

  - One way to look at the results, in a positive way, is as follows:

Rating	Percent
Fails to meet expectations	15%
Equals expectations	25
Exceeds expectations	60
Total	100%

  - In view of the many user complaints about vendors' systems received during the interviews, INPUT would tend to downgrade the ratings somewhat because users feel "locked in" to their systems and do not want to play them down.

    . Eighty percent of the users stated that if they were to start again today, they would buy from the same vendors.

    . A typical user quote is, "The systems have many inadequacies, but they are the best available in the industry."

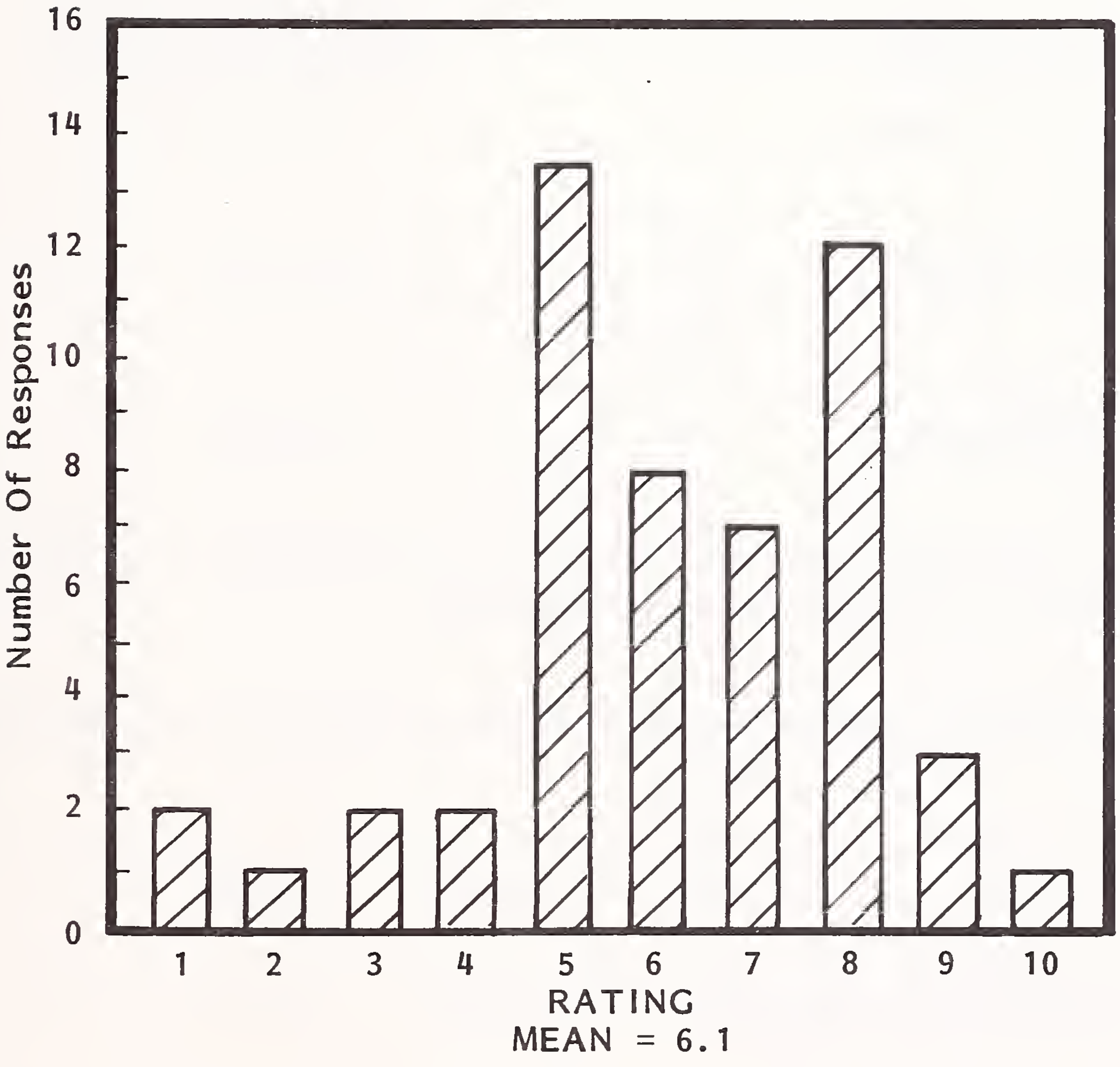
- Whatever the nuances may be, things seem to bode well for user acceptance of CAD/CAM systems.

B. COSTS

- User expenditures for CAD/CAM systems vary tremendously because the users' needs are so different.

EXHIBIT V-4

EXTENT TO WHICH CAD/CAM INSTALLATIONS
MEET USER EXPECTATIONS
AT THE TIME OF PURCHASE



1 = Totally Fails to Meet Expectations
5 = Equals Expectations
10 = Far Exceed Expectations

- At the low end is the user who licenses SCICARDS routing, placement, and schematics software to run on an in-house installation in a timeshared mode.

- At the top end is the large VLSI manufacturer with many systems and ongoing software development.

• Average annual expenditures approximate to the following:

Type of User	Annual Expenditures for Externally Procured Hardware and Software
Small PCB Design	\$100-200 thousand
Large Electronic Firms - PCB Design	\$2 million
Large VLSI Manufacturers	\$6 million

- For the reasons previously stated, cost justification of CAD/CAM systems is no problem for any of these users.

• The average cost per workstation, not including CPU costs, is, and is projected to be:

	1981	1986
Average Cost Per Workstation (\$ thousands)	\$65-85	\$20-30

• The average cost for use of a CAD/CAM workstation is forecasted to remain at about \$35 per hour over the next five years:

- Although it is not a prevalent practice, some companies charge departments for use of the system as a means of recovering CAD/CAM costs.

- Costs of training new users of CAD/CAM systems must also be considered.

  - Training times are running as follows:

    - Training time to initial use - 3 weeks.

    - Training time to full proficiency - 28 weeks.

VI USER PREFERENCES AND NEEDS

VI USER PREFERENCES AND NEEDS

A. LOCAL VERSUS CENTRAL INTELLIGENCE

- VLSI design functions are now so complex that they cannot be handled in a timeshared mode by the central processor of a multiple station turnkey system without slowing response times, resulting in an inordinate length of time to accomplish designs.

- The need is for more local intelligence at the workstation allowing for a transition to truly distributed data processing systems over the next five years, as shown in Exhibit VI-1.

  - CAD users are turning to large graphics processors, interfaced with large mainframe CPUs, to drive the workstations.

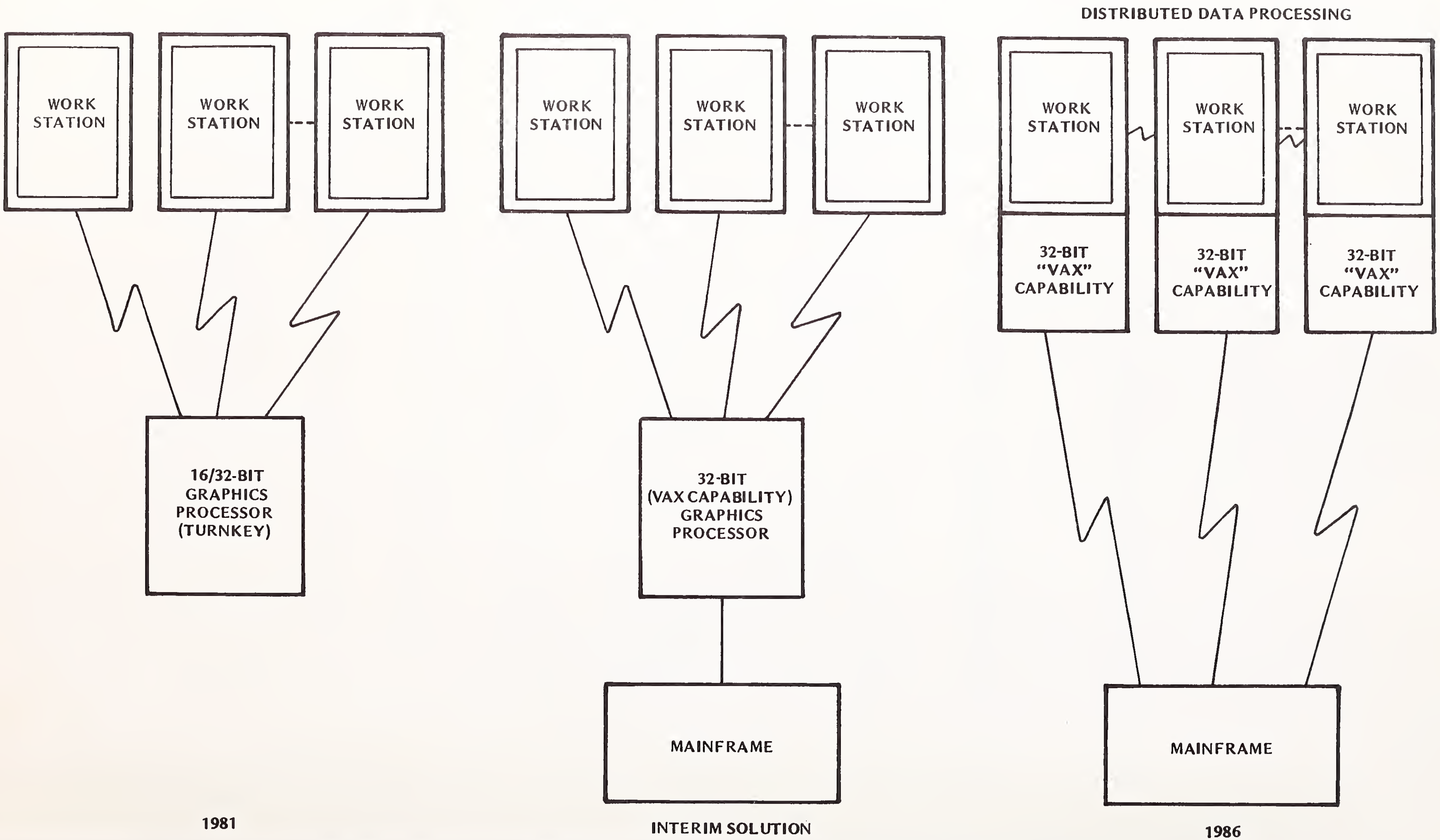
  - Large functions, such as design rules checking, are being off-loaded to the central CPU.

  - This is a good first step, but it is only an interim solution.

- Advances in VLSI technology over the next five years will make it possible to provide the equivalent of a full VAX capability at the workstation, at a price in the range of $20,000 to $30,000 per station.

EXHIBIT VI-1

PROGRESSION OF SYSTEMS CONFIGURATIONS
FOR VLSI COMPUTER-AIDED DESIGN
(LOCAL VERSUS CENTRAL INTELLIGENCE)



- The resulting distributed data processing system configuration, with workstations networked to each other and to a central mainframe CPU, will alleviate the limitations inherent in a central graphics processor configuration.

  . Large processing can be handled by the CPU, but it is expected that there will be more communications and load-sharing between the workstations themselves in future DDP systems than there will be between the workstations and the CPU.

- Advances in CAD/CAM software, in combination with improved system configurations, are expected to allow the systems to more clearly meet the design needs of the industry over the next five years.

B. INTEGRATION

- Computer-based systems can assist in generating design engineering data (CAD) and in performing functional manufacturing operations (CAM). Initial CAD/CAM integration occurs when data generated by CAD systems are used by CAM systems.

  - Full integration occurs when both functions are integrated into a single system.

- Approaches are required which will combine in interactive and integrated format all of the functions required for complex electronic design.

  - These integrated systems will be deemed to be the "next generation" of electronic systems.

  - While vendors in the electronic marketplace feel that they are providing an adequate array of functional and application capabilities to

users, users are dissatisfied with vendor offerings and, generally, believe that vendors do not have adequate knowledge of their specific requirements for expanded capabilities in integrated application areas.

- INPUT believes that integration of CAD/CAM, including shared data bases, within the electronic environment will emanate from software development efforts within five years, that the leadership for integration will come from the user community, and that the vendor community will play a lesser role, at least initially.

- User views of industry progress toward CAD/CAM integration are shown in Exhibit VI-2.

  - Little progress has been made to date, but future needs are compelling.

    . Users' views reflect this, as evidenced by the high ratings for 1986. Completely integrated systems are expected within five years.

- Typical user comments concerning the issue are:

  - "There are lots of things to be done in CAD first before integration is possible - it is a resource allocation problem."

  - "Very little progress has been made, but integration is badly needed."

  - "We are not optimistic about progress in the next five years."

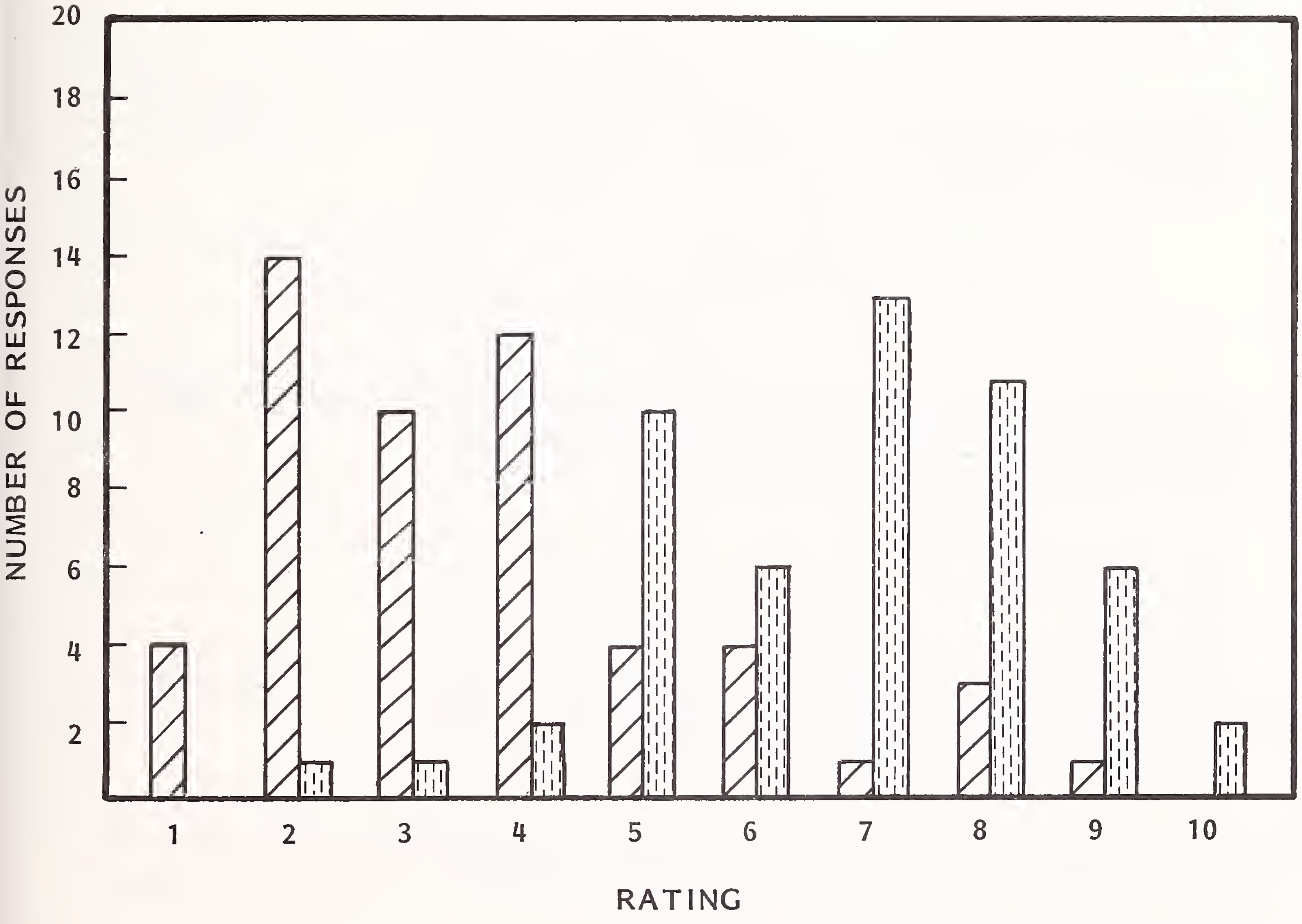
  - "Great interest but little progress."

  - "Very little progress, a most critical problem."

  - "The effort is just getting started."

EXHIBIT VI-2

USERS' RATINGS OF
INDUSTRY PROGRESS TOWARD
CAD/CAM INTEGRATION



1981 Mean = 3.7

1986 Mean = 6.8

1 = NO PROGRESS
10 = COMPLETELY INTEGRATED

- "VLSI is still a cottage industry."

- Established trends toward integrating design engineering data bases with other organizations are shown in Exhibit VI-3.

- One of the largest unmet needs users express is to first achieve a good engineering data base, and then integrate it with other organizations.

- Users clearly express the view that integration of data bases will occur within the next five years.

- Among other consequences will be rapid obsolescence of IC manufacturing facilities.

  - One of the major VLSI suppliers has had to rebuild parts of its manufacturing facilities eight times over the last ten years.

- Integration of engineering data with other functional data bases will result in greater efficiency of data use and less redundancy.

- There are considerable obstacles to the integration of CAD and CAM, as shown in Exhibit VI-4.

  - INPUT agrees with the users that complexity and the attendant lack of industry standards are formidable problems.

  - However, the large resource allocation problems associated with costly implementation are not evident to the users and will be a much larger obstacle than the ratings indicate.

  - Also understated by the users' responses are the inherent organizational problems.

EXHIBIT VI-3

ESTABLISHED TRENDS TOWARD INTEGRATING
DESIGN ENGINEERING DATA BASES
WITH OTHER ORGANIZATIONS

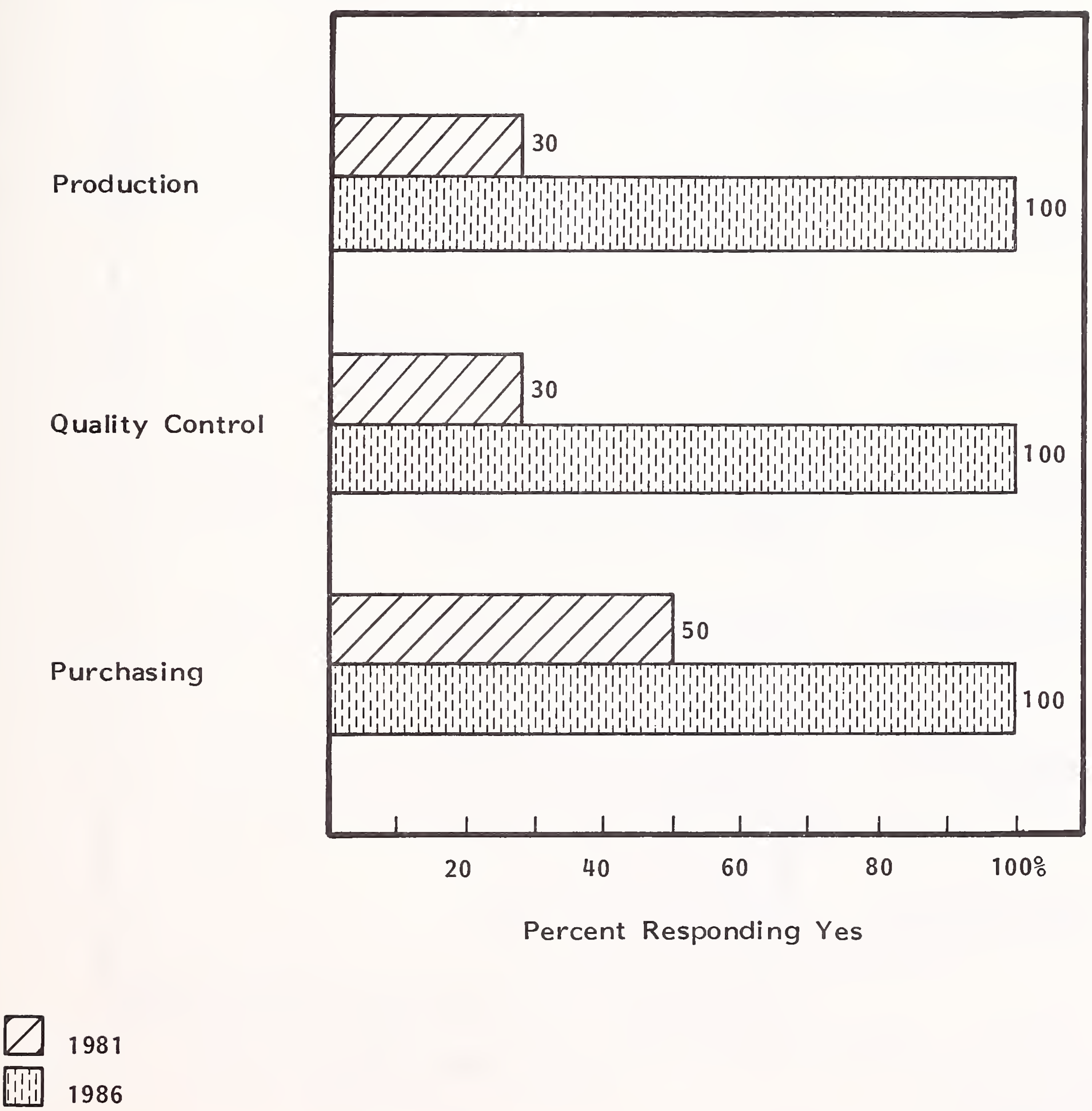
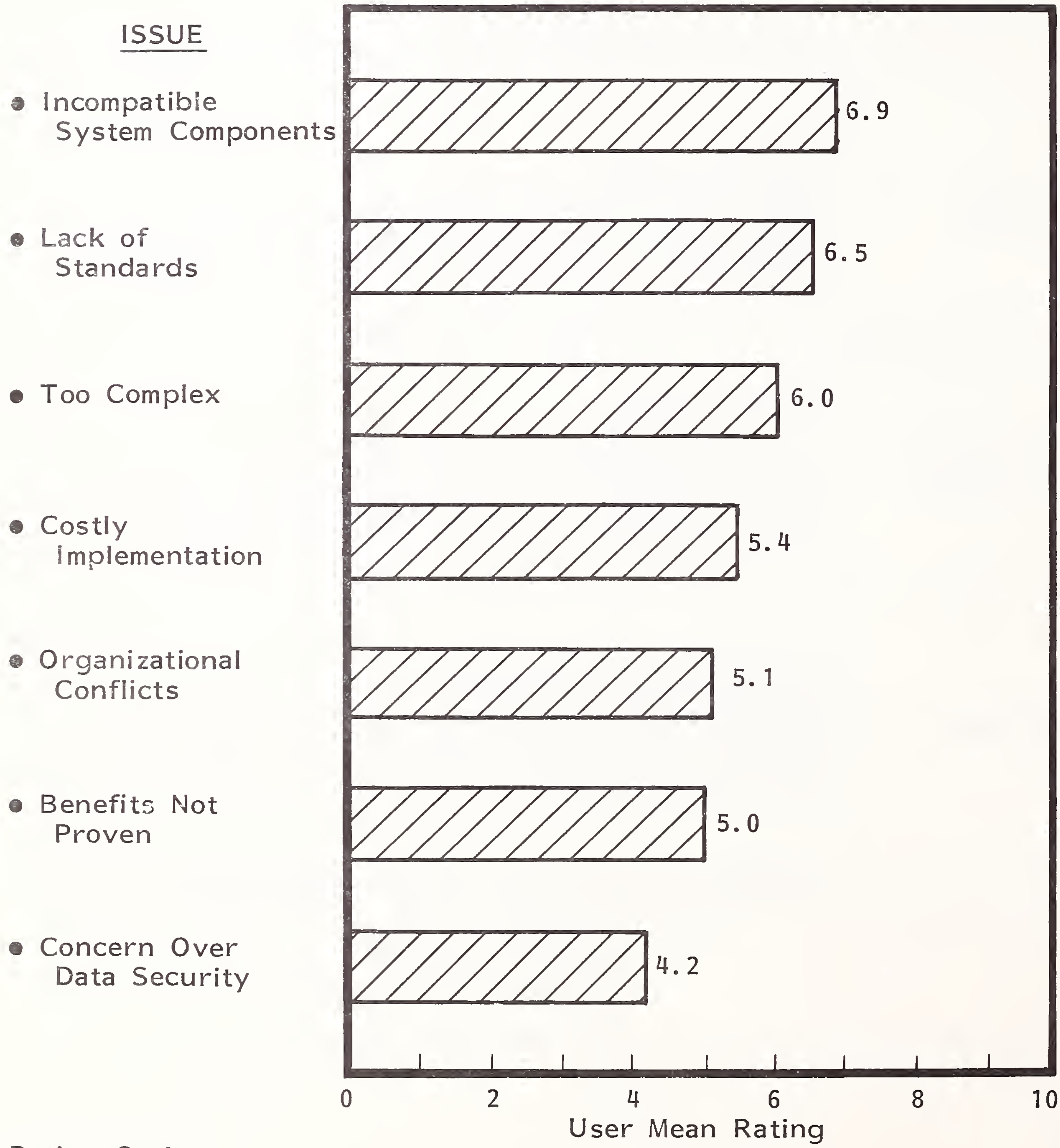


EXHIBIT VI-4

PERCEIVED OBSTACLES TO CAD/CAM INTEGRATION



Rating Scale:
1 = None
10 = Very Large

*SEE APPENDIX B FOR DETAIL

- Integration of CAD/CAM will affect the traditional roles of engineering, manufacturing, and other functional divisions/ organizations.

- Integration implies changes in the way the company is run and controlled.

- For these reasons, it is up to top management to take the initiative in CAD/CAM integration, a nontrivial decision in light of the costs involved and the organizational implications.

- Stated again, the driving force behind CAD and its integration with CAM is software related technology advances, which stem from university, government, and industry-based research efforts.

C. SOFTWARE REQUIREMENTS

- The electronic market segment is one in which needs already exist for creation of "next generation" software and supporting hardware systems.

  - Major VLSI manufacturers have a need for capacity beyond that which can be purchased from turnkey vendors.

  - Although some of these companies will continue to buy systems from turnkey vendors, internal development efforts will result in systems with capabilities far beyond those which can be purchased commercially.

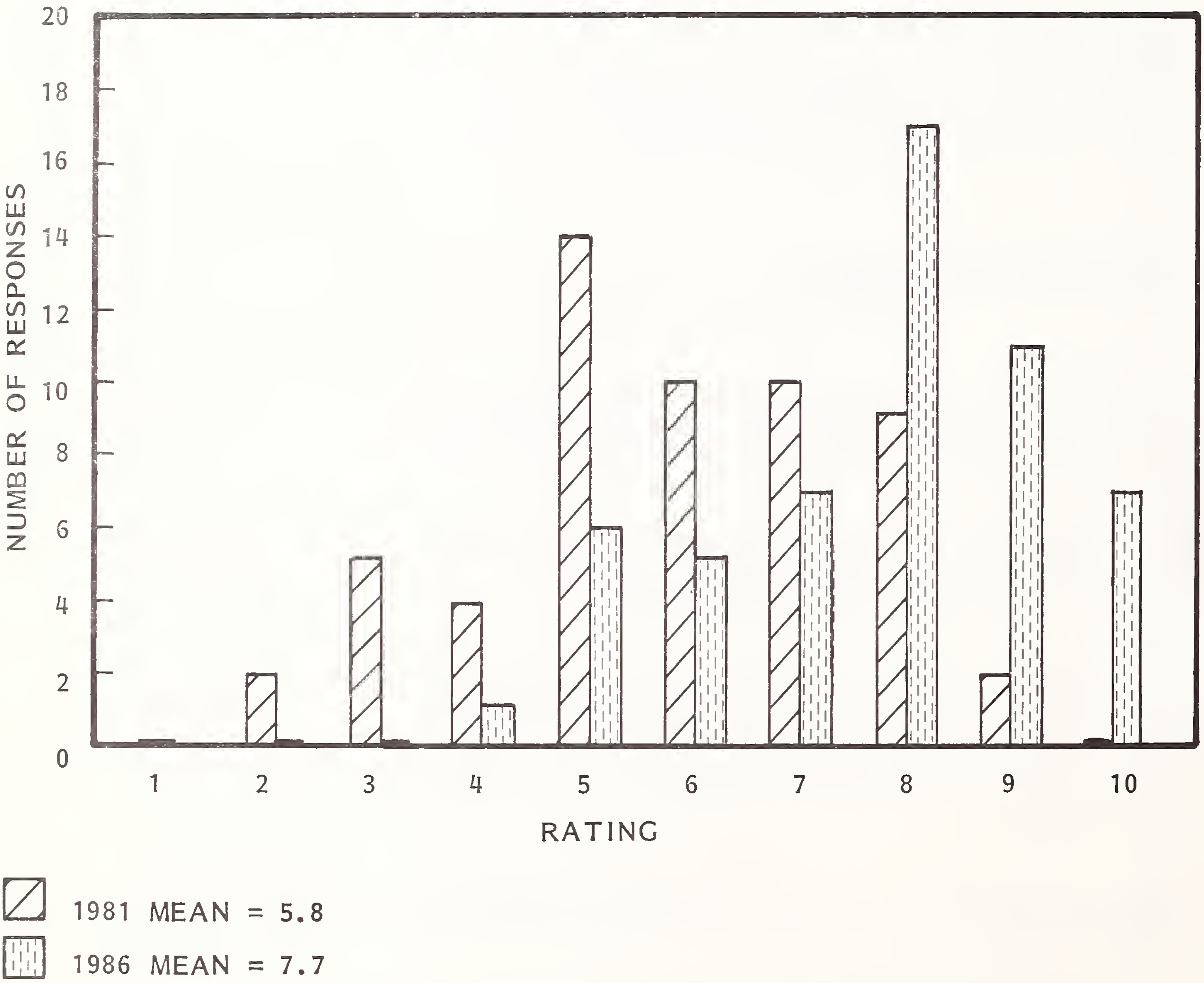
- The overall adequacy of CAD/CAM software is shown in Exhibit VI-5.

  - User ratings accurately reflect the present inadequacy of today's software to handle complex designs.

EXHIBIT VI-5

USERS' RATINGS OF

OVERALL ADEQUACY OF CAD/CAM SOFTWARE



1 = VERY POOR
10 = EXCELLENT

- The optimism expressed by the users that considerable improvements will be forthcoming is justified by the great deal of effort being applied to software development.

- Software research and development efforts are focused on the individual features of the CAD/CAM systems for integrated and printed circuit board design previously discussed in Chapter III.

- Research results usually find their way into industrial use as independent software packages, such as those reported by users in Exhibit VI-6.

  - The number of software packages reported here is very small compared to the universe of such packages available.

    - VLSI design houses often employ scores of such packages.

    - Packages such as Berkeley's SPICE, Stanford's SUPREM, and the industrially developed SCICARDS are very highly regarded by users.

    - The list is constantly being upgraded as superior software is developed.

- Systems and applications software enhancements are most often supplied by vendor software releases. The following sources provide enhancements ranked in order with I most important:

Source	Ranking
Vendor Software Releases	1.0
In-House Software Development Group	0.5
Software Consulting Services	0.2

EXHIBIT VI-6

MOST FREQUENTLY USED SOFTWARE PACKAGES

PACKAGE	DESCRIPTION	RANKING BY FREQUENCY OF USE*	RATING OF ADEQUACY**
SPICE	Simulation Program - U.C. Berkeley	1.0	6.7
TEGAS	Logic Simulation-Digital	0.6	5.5
LOGAP	Logic Simulation-Digital	0.6	4.8
SCICARDS	PCB Design - Scientific Calculations Inc.	0.4	8.0
SUPREM	Process Simulation-Stanford University	0.3	8.7

* 1 = MOST FREQUENTLY USED
** 1 = VERY POOR
10 = EXCELLENT

- Vendor software releases are a considerable problem to the users, who feel that the programs are not sufficiently debugged prior to release, and that the implementation instructions are not sufficiently clear.

  . This is a popular topic at user group meetings.

- Undoubtedly, releases supplied by in-house development groups and by consultants have similar problems.

• Users and vendors feel that their ability to provide software that is adequate to meet industry needs would be considerably enhanced by the adoption of a workable set of industry standards. Examples are:

- IGES (Initial Graphics Exchange Standard), the National Bureau of Standards' ANSI standard.

  . This effort is funded by the federal government under I-CAM.

  . IGES is backed by a number of user groups and others in the industry.

- SIGGRAPH-CORE the proposed standard provided by the Special Interest Group on Graphics of the Association for Computing Machinery.

- Whether these or other standards are adopted is highly questionable.

  . Users generally feel that neither of these proposed standards will be useful in electronics design, and hope for a de facto industry standard to evolve.

- University researchers make the opposite case.

. They feel that the structured design approach to VLSI circuits is just in the research phase, is in a considerable state of flux, and that settling too soon on software standards would be detrimental to research purposes.

D. RELIABILITY REQUIREMENTS

- Users expect greater than 95% system availability, and they are generally falling far short of that expectation, as shown in Exhibit VI-7.

  - Experience with systems downtime is quite variable.

    . One computer manufacturer is experiencing 98% system availability and attributes it to the efforts of an independent outside field service contractor.

    . On the other hand, one of the large VLSI suppliers has equipment down 25% of the time.

  - Even taking into account that hard failures are relatively infrequent, and that most times the system continues to function in a degraded mode, it is clear that system reliability of electronic CAD/CAM systems is a major problem.

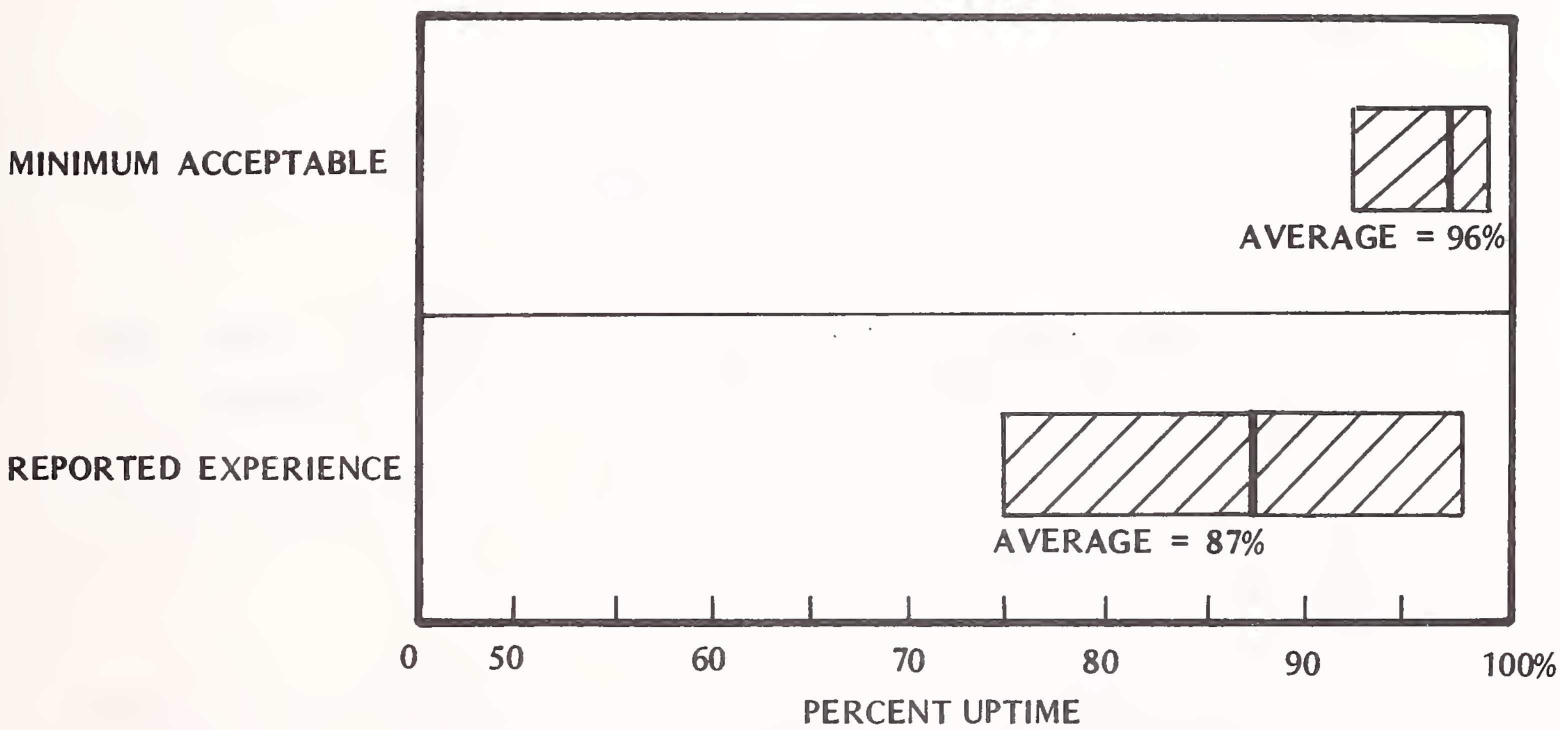
- Turnkey vendor supplied field service problems are well known in the industry.

  - The problems the turnkey vendors face stem from basic considerations.

    . Field service personnel must maintain equipment from different manufacturers running under complex systems and applications software, which makes the task difficult.

EXHIBIT VI-7

SYSTEM AVAILABILITY EXPECTED AND RECEIVED



The shortage of qualified CAD system field service personnel has created a bidding war among turnkey vendors with the result being rapidly increasing costs and very high turnover rates.

- Mean time to respond to service calls varies from "instant" where on-site capability is maintained, to as much as 48 hours in some instances.

  - However, initial response is generally less than 24 hours (same day response) and is not a big problem.

- Mean time to repair (MTTR) runs from a few hours to a few weeks depending on the nature of the problem and is of considerable concern to users.

  - Calma users were receiving a MTTR of 18 hours on the average with as high as 66 hours.

- Users' views of the overall quality of field service provided are shown in Exhibit VI-8.

  - In view of the various problems just discussed, INPUT views these ratings as much too optimistic, probably reflecting product loyalty.

  - Field service continues to be a major problem for turnkey CAD/CAM users.

- As a factor in the total purchase decision for future CAD/CAM systems, the quality of field service the vendor supplies accounts for 30% to 40%, which is inordinately high and should be reckoned with by turnkey vendors.

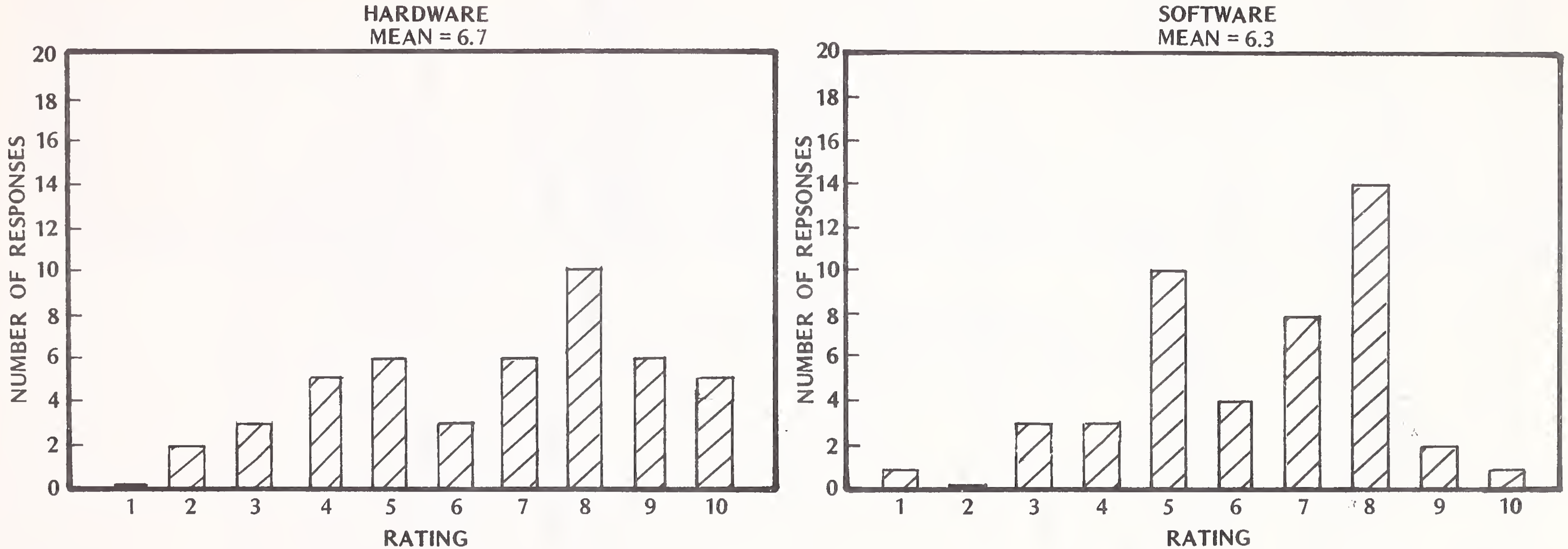
E. DISPLAY TECHNOLOGY REQUIREMENTS

- Display technology requirements for CAD/CAM systems in the printed and integrated circuit industry are being met by raster scan displays and this

EXHIBIT VI- 8

USERS' RATINGS OF

OVERALL QUALITY OF FIELD SERVICE PROVIDED



1 = COMPLETELY INADEQUATE 10 = SUPERIOR

technology will become even more dominant over the next five years, as shown in Exhibit VI-9.

- The low-cost, high-resolution monochrome graphics terminal market has been dominated by the direct view storage tube since it was developed by Tektronix in the early 1970s.

  - However, this technology has very limited applications in electronic CAD/CAM systems today and users see future applications of the storage tube being insignificant because of basic limitations such as:

    - Monochrome image.

    - Lack of selective refresh.

    - Low light intensity.

    - Difficulty of obtaining hardcopy images.

    - Limited tube life.

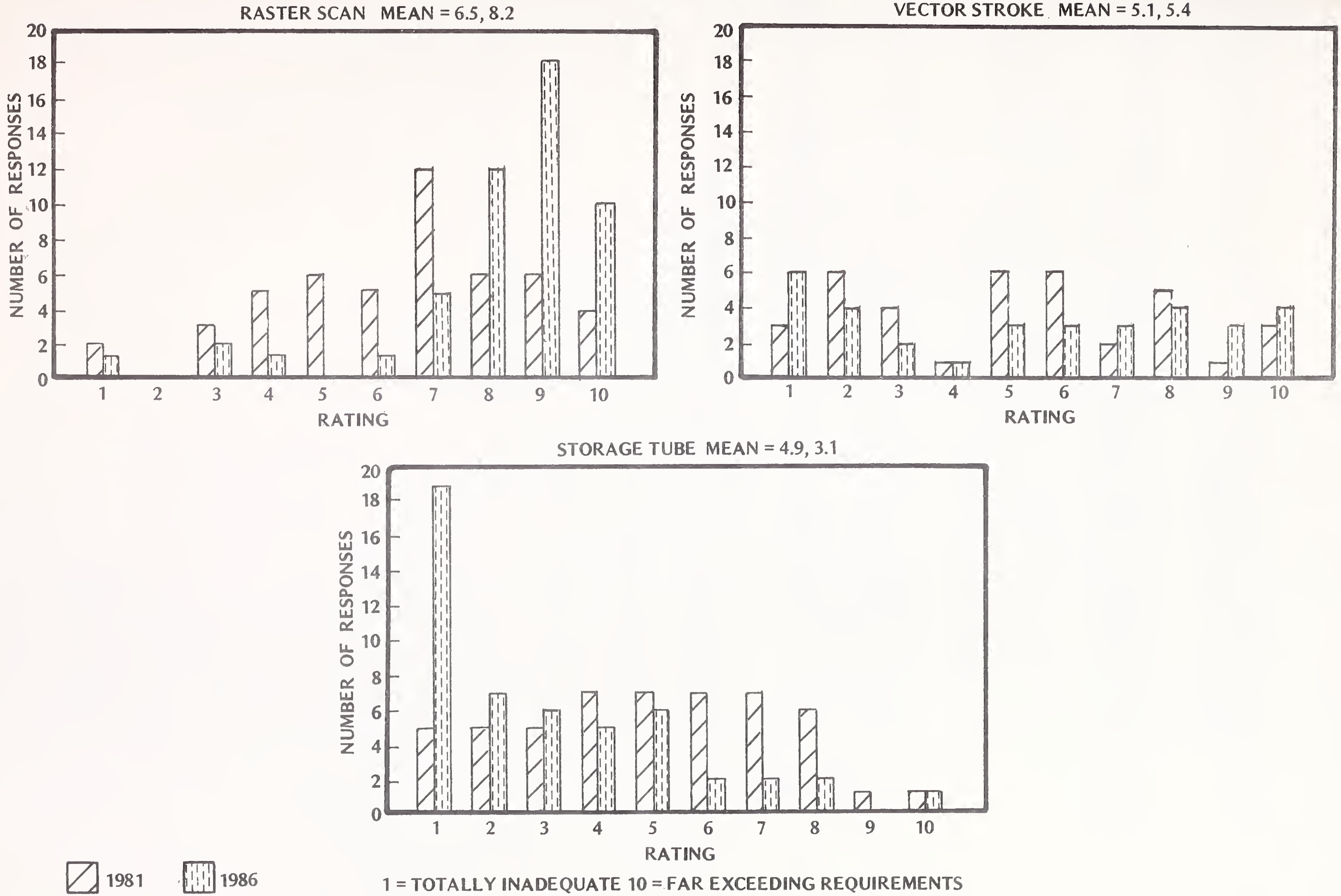
- Another contending technology, the vector stroke writer or calligraphic terminal, offers very high resolution and is in widespread use in some mechanical CAD/CAM systems, but is used much less in electronics applications.

  - Vector stroke terminals are expensive, provide low-light intensity, and do not provide color images; disadvantages which far offset any advantage high resolution offers electronic users.

- Clearly the dominant technology will be the bit-mapped raster scan.

EXHIBIT VI-9

USERS' RATINGS OF DISPLAY TECHNOLOGY REQUIREMENTS



1 = TOTALLY INADEQUATE 10 = FAR EXCEEDING REQUIREMENTS

- This graphics technique has established itself as the rapid growth technology in color systems.

- These terminals require much larger local memory because an address has to be calculated for each picture element (pixel).

  . This requirement is now easily met due to economic and performance gains in semiconductor technology. Users generally feel that "memory is free" for this purposes.

- High resolution is available (1,024 X 1,024 lines) in raster scan terminals which is quite adequate for user needs.

• The benefits of a raster system are very significant to CAD/CAM users; for example:

  - Moderate cost.

  - Wide range of selectable color hues.

  - Continuous shading capability.

  - Display of a large number of vectors without serious compromise on speed.

  - High light intensity.

  - Ease of obtaining hard copy.

  - Long tube life.

  - Data content without flicker.

  - Selective erase.

- Color displays are now economically available and will become essential to users over the next five years, as shown in Exhibit VI-10.

  - Although some will argue that multilayer displays can be handled in monochrome by various shading techniques, the displays are much more vivid and interpretable in color.

  - The human factor aspects of color are far superior.

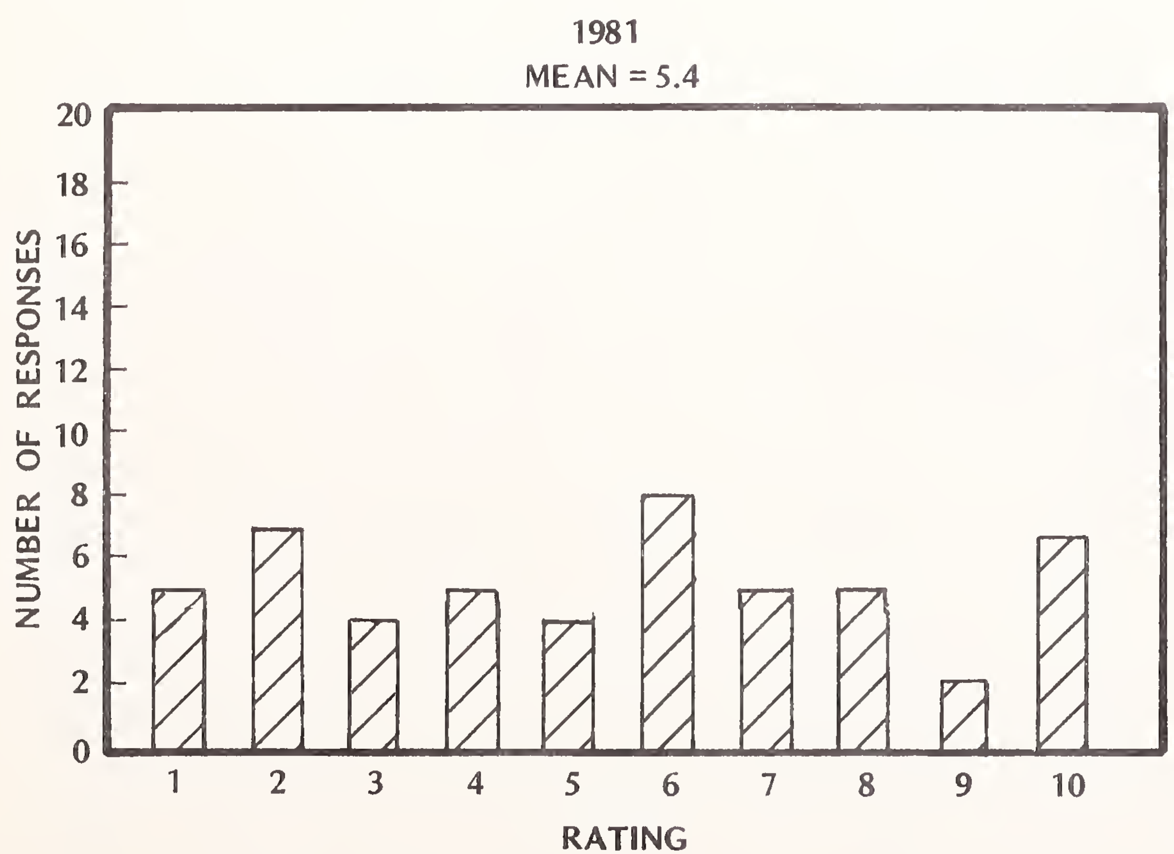
  - Color graphics are now gaining widespread acceptance.

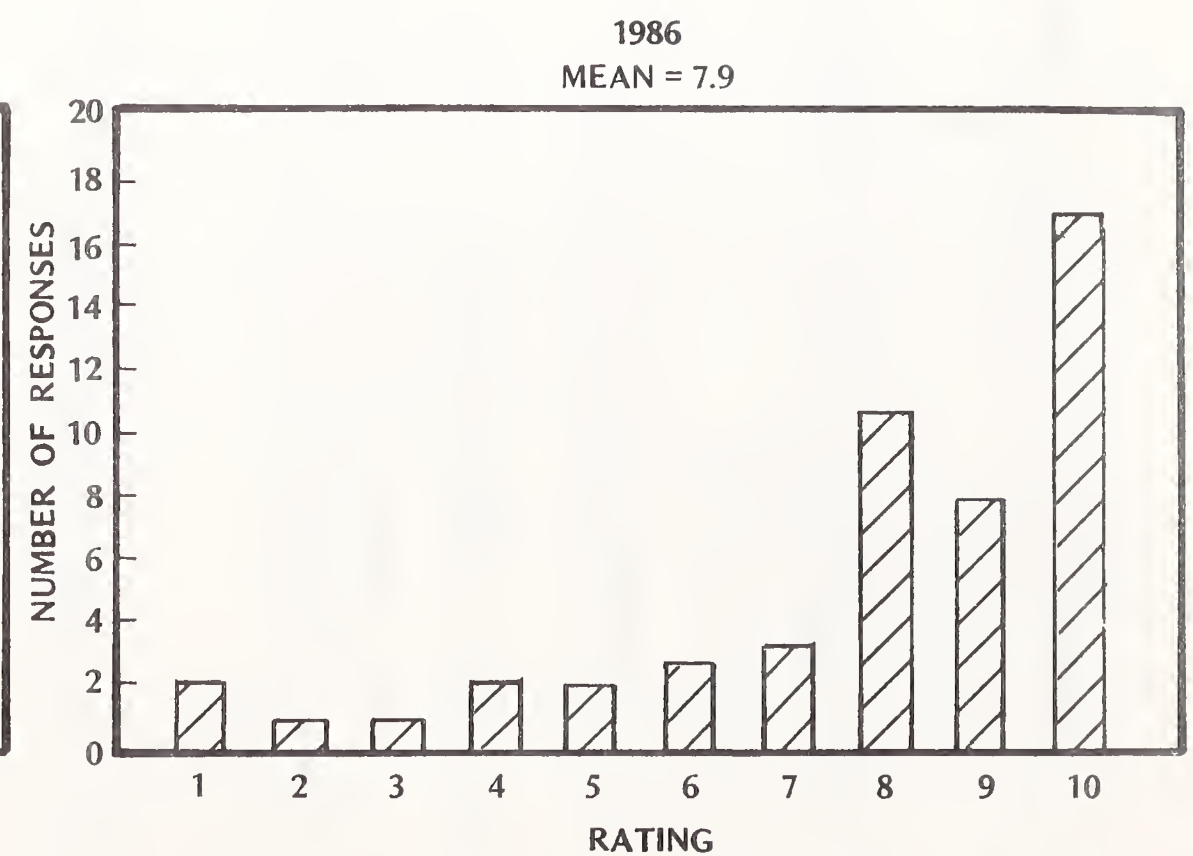
  - Users' experience, generally, is that once a designer has worked on a color terminal, he will never be as happy or productive on a monochrome terminal.

    . Since costs are no longer prohibitive, most users feel that color is now essential for electronic design.

EXHIBIT VI-10

USERS' RATINGS OF
IMPORTANCE OF COLOR TERMINALS





1 = NO REQUIREMENT 10 = ABSOLUTELY ESSENTIAL

VII VENDOR TRENDS

VII VENDOR TRENDS

A. LOCAL VERSUS CENTRAL INTELLIGENCE

- User needs for central intelligence are expected to be met by the vendors over the next five years.
  - Distributed data processing systems, with "VAX" level intelligence at each workstation, at a reasonable cost, are expected to solve the problems inherent in a central graphics processor for PC and IC designs.

- Typical vendor comments on this are as follows:
  - "The 32-bit, VAX size, workstation for $20,000 is plausible over the next five years; Xerox has just announced a graphics workstation with CAD capability for $15,000, linkable to anything you want."
  - "We can expect VAX capability on a chip in five years for under $20,000 with ½ megabyte storage."
  - "We will see 32-bit VAX capability in a desktop computer selling for less than $20,000 in less than seven years."
  - "CPU interface is an easy option but will probably not be necessary."

- "Trend is toward small 32-bit processors. By 1986 they will be universally required."

- "A price of $20,000 will be tough for a VAX sized terminal because peripheral equipment is not coming down in price as fast as the CPU is: I would go along with $30,000."

B. INTEGRATION

- Vendors have little knowledge of the status of CAD/CAM integration.

- Users' and vendors' views are quite similar.

  - Both view integration as being in its infancy, and express guarded optimism that progress will be made over the next five years.

- INPUT believes that the reality of the situation is that users must first define their approach to solving the problems of organization, resource allocation, and technology before vendors can be expected to react.

C. SOFTWARE REQUIREMENTS

- The central theme of this study has been reiterated several times: the critical industry need for greatly improved software which, along with expected improvements in price/performance of equipment, will allow CAD/CAM systems to meet the design needs of printed and integrated circuit manufacturers.

- The companies most likely to be able to provide software solutions are those who are working most closely with the university efforts, principally:

- DEC.

- IBM.

- Hewlett-Packard.

- Xerox.

● At the 1981 ACM IEEE Eighteenth Design Conference many promising electronic software development programs were described.

  - The vendors just mentioned were prominent contributors.

  - Also major contributors were the systems companies who fabricate their own PC and VLSI devices, such as:

    . Bell Labs.

    . GTE.

    . RCA.

    . ITT.

● Major contributions to software breakthroughs are also expected to come from VLSI manufacturing companies, such as:

  - Texas Instruments.

  - Intel.

  - Fairchild.

  - National Semiconductor.

- INPUT can see no evidence that needed software breakthroughs will come from the turnkey vendors.

  - They will continue to improve their systems, but these companies are not tackling major needs like:

    - Real time design rule checking.

    - Topography verification methods.

    - Testing.

    - More powerful routers.

    - Integration.

- It is within the context of this view of the vendor community that INPUT expects user needs to be met.

D. RELIABILITY REQUIREMENTS

- Reliability of CAD/CAM systems should improve over the next five years for two reasons, and approach more closely the computer industry norm of 98% uptime.

  - Equipment will be inherently more reliable in the future as advances in integrated circuit techniques are applied.

  - Vendors are addressing the problems and are finding solutions.

    - Some turnkey vendors are guaranteeing 95% reliability today.

- Software reliability is expected to improve.

E. DISPLAY TECHNOLOGY ISSUES

- Vendors see the same trends in display technology as users.

  - Storage tubes are not important for future electronic CAD systems.

  - Vector stroke (Calligraphic) displays are not an important factor, but there will always be a place for them in limited applications.

  - Color raster scan is dominant today and will be increasingly so in the future.

    - Definition of 1,000 lines is available today, which is quite adequate; it will go to 2,000 lines in the future, which exceeds requirements.

    - Memory requirements are met by the present state of the art in integrated circuits.

- Vendors feel that color is essential and, incidentally, rate it much higher in importance for electronic applications than for mechanical or architectural/ engineering design.

- In view of the vendor activity in color raster scan terminals, it seems evident that user requirements will be fully satisfied.

APPENDIX A: CASE STUDIES

APPENDIX A: CASE STUDIES

A. GENERAL

- Nine electronic CAD/CAM users that were interviewed on-site by senior INPUT personnel were selected as specific examples of the user community in order to illustrate some of the general findings of this applications volume.

  - The companies remain anonymous but their actual approaches and experiences are reported in the following sections.

B. A $740 MILLION EQUIPMENT MANUFACTURER

- The company designs and manufactures LSI devices and PCBs for its own use.

- The processing power for its custom designed in-house system consists of:

	Equipment	Cost
-	IBM 4341 for design	$1.00 million
-	VAX for implementation	0.75
-	2 CPUs of their own manufacture	1.00
	Total	$2.75 million

- In addition it uses the following turnkey vendors:

  - Computervision for IC design and for digitizing PCBs.

  - Scientific Calculations, Inc. (SCICARDS) for PCB placement and routing.

- The company spends $300,000 per year for CAD/CAM research and development - less than 0.1% of annual sales.

- The present CAD/CAM system is not regarded as being up to the state of the art.

- The turnkey CAD/CAM system falls short of the company's expectations at the time of purchase because of problems in service, field maintenance, and software.

- Response times are running about four seconds which is regarded as "bearable," but is at least twice the company's requirements.

- Major maintenance problems are being encountered with both hardware and software maintenance which relate mainly to the turnkey CAD/CAM vendors.

C. A $300 MILLION MANUFACTURER OF LARGE-SCALE COMPUTERS

- The company designs and manufactures LSI devices and PCBs for its own equipment.

- The CAD/CAM mainframe is of its own manufacture.

- Its first turnkey system was from Calma, but it had a bad experience with it so it turned to Applicon.

  - The Applicon system could not handle IC design and is presently used only for PCBs.

  - IC design is still done on the Calma GDS-I, a three-station $400,000 turnkey system.

- The present CAD/CAM systems are regarded as "primitive," and the system is being upgraded to a VAX-based system.

- Six million dollars per year are being spent on CAD/CAM research and development - 2% of annual sales.

- Response times are running 3 seconds for digitizing and 8 to 10 seconds for refresh, as compared to requirements of I second and 5 seconds, respectively.

- Reliability of the hardware and software is excellent, which the company attributes to the services of an independent outside service company.

D. A $1 BILLION MANUFACTURER OF VLSI DEVICES

- The CAD/CAM system consists of the following:

Equipment	Cost
- 20 Calma systems at $500,000 each . Supports 75 IC workstations	$10.0 million
- 3 in-house systems of its own manufacture, . At $1.5 million each	4.5
Total	$14.5 million

- A remote computing service from CDC is also used.

- The company spends 2% of its total R&D budget on CAD/CAM.

- Expectations at the time of purchase were generally fulfilled and it would buy from the same vendor again.

- Response times are not adequate for a loaded system.

- Maintenance is excellent thanks to three resident Calma field engineers.

E. A $300 MILLION ELECTRONIC SYSTEMS HOUSE

- This company, a subsidiary of a very large conglomerate, designs and manufactures PCBs for its own systems, largely for military applications.

- The system consists of:

  - An in-house Data General Eclipse.

  - A turnkey Computervision CADDS-I system costing $250,000.

  - Russell Briggs designed software, DA version 8, costing $90,000.

- The company feels that "the systems were oversold, and did not live up to expectations at the time of purchase."

  - It would not buy from the same vendor again, but would reinvestigate the field to take advantage of new innovations.

- Response times on CADDS-I are running 10 to 15 seconds as compared to requirements for 0.5 seconds for simple instructions and complete refresh in 5 seconds.

- Serious maintenance problems exist for the hardware but not for the software.

  - The company feels that "vendors don't respond properly, and that often they can't fix the problem anyway."

F. A $1 BILLION INTEGRATED CIRCUIT MANUFACTURER

- This company, a subsidiary of a large international conglomerate, designs and manufactures printed and integrated circuits.

- The CAD/CAM system consists of:

  - An IBM-370 series in-house mainframe.

  - Eleven turnkey systems from Computervision, Calma, and Applicon, averaging $400,000 each for a total cost of $4.4 million.

- The turnkey systems are generally well thought of:

  - Response times are adequate.

  - Vendors are responsive.

- However, the company regards them as inadequate for future needs and has embarked on a very ambitious, well funded upgrade in all areas, with the goal of having one of the best VLSI CAD/CAM systems in the industry in two years.

- The new system configuration will be all custom designed and will not employ turnkey systems.

- The planned system configuration will be based on:

  - Cyber series 205 mainframe.

  - VAX 11-780 graphics processors.

  - Multiple, networked $50,000 workstations with greatly improved processing capability.

- As part of the plan, the company also will provide several million dollars a year to support software R&D in selected universities.

G. A $400 MILLION DIVISION OF A MAJOR COMPUTER MANUFACTURER

- The company designs and manufactures VLSI devices for its own use.

- The CAD/CAM system consists of:

  - In-house graphics processor of its own manufacture.

  - Five Calma workstations.

  - NCA software for design rules checking.

- Expectations at the time of purchase were met.

- They are "very satisfied with Calma, and would buy from them again."

- Response times are running 4-5 seconds, which is regarded as "adequate for now."

- There are serious problems with maintenance of the Calma hardware.

  - "Do not have adequate service people, do not stock sufficient parts, Calma admits to the problem, they cannot keep their people."

H. A $800 MILLION DIVISION OF A LARGE ELECTRONIC SYSTEMS COMPANY

- It has a well established PCB capability and is just getting into LSI.

- This division, devoted to radar systems, is one of eight divisions of the company.

  - Each division has its own autonomous CAD/CAM capability, there is no corporate interest in making these compatible.

- The CAD/CAM system for mechanical and electrical design consists of:

  - An IBM in-house system running under CADAM software.

  - Two Computervision turnkey systems costing $1 million.

  - One Calma system, GDS-II at $400,000.

  - Remote computing service, CDC Cybernet.

- The company is not satisfied with the Lockheed CADAM system, and would not bring it in if it had it to do over again.

  . The basic reason for this is that compatibility with Computervision is too big a problem.

- The PRANCE module of CADAM for PCB design will be added as soon as it becomes available.

• Response times are adequate.

  - CADAM is less than 1 second.

  - Computervision is variable.

  - Calma is around 4 seconds.

I. A MULTI BILLION DOLLAR EQUIPMENT MANUFACTURER

• The company has a very sophisticated PCB and VLSI capability for use in its own equipment and for outside distribution.

• The CAD/CAM system includes 26 in-house systems capable of supporting 104 workstations, of which only one-half are presently being used.

• The CAD/CAM system includes (a partial listing):

	Equipment	Cost
-	In-house Amdahl	$5.0 million
-	In-house IBM	2.0

-	4 Calma terminals (not interfaced)	0.6
-	6 Applicon terminals	0.8
	Total	$8.4 million

- Even with this large system devoted to VLSI design, the company experiences serious response times and plans to go to a completely distributed system within the next five years.

  - Early attempts to do IC design on standalone turnkey systems failed and the company soon decided that it could not depend on the turnkey vendors' systems and would have to custom design its own, including all software development.

  - Attempts to use remote computing services from CDC also failed because response times were much too slow.

- PCB design is done in batch mode on the Amdahl using Automated Systems Inc., PRANCE software, which the company regards as the most powerful PCB router in the industry.

  - The largest number of unroutes they have experienced on a six-layer, 144 IC board is nine.

- It is a large supporter of university software R&D, which is almost universally done using DEC hardware.

J. AN OVER $1 BILLION VLSI MANUFACTURER

- The company designs and manufactures LSI and VLSI devices for worldwide distribution.

- Its policy is to continually upgrade the system to keep it current with the most advanced technology.

- The CAD/CAM system includes:

Equipment	Cost
- VAX processors	$ 5.0 million
- IBM 3030	3.0
- CRAY I (to be replaced with CYBER 205 in 1.5 years)	7.5
- 20 Applicon AGS-860	10.0
- 4 Calma GDS-I	2.0
Total	$27.5 million

  - Plus $1 million per year for software from UCS and CDC.

- It regards the system as the best in the industry, but still inadequate for future needs, and plans to go to a distributed system.

- Response times are "not acceptable."

- Maintenance of hardware and software is a problem.

  - "A very big problem, support is twice as expensive and half as good as it should be."

APPENDIX B: DATA BASE

EXHIBIT B-1

INTERVIEW PROGRAM

TYPE	NUMBER OF INTERVIEWS		
	ON-SITE	TELE-PHONE	TOTAL
User	-	-	-
• IC	14	12	26
• PCB	7	22	29
• IC & PCB	3	1	4
Subtotal	24	35	59
Vendor	13	-	13
Total	37	35	72

EXHIBIT B-2

USER INTERVIEWS BY COMPANY SIZE

TYPE OF USER	NUMBER OF INTERVIEWS BY COMPANY SIZE ($ billions)			
	SMALL <$0.1	MEDIUM $0.1 - $1	LARGE >$1	TOTAL
IC	5	7	14	26
PCB	5	3	21	29
IC & PCB	0	0	4	4
Total	10	10	39	59

*AVERAGE SIZE OF USER RESPONDENT = $365 MILLION IN SALES

EXHIBIT B-3

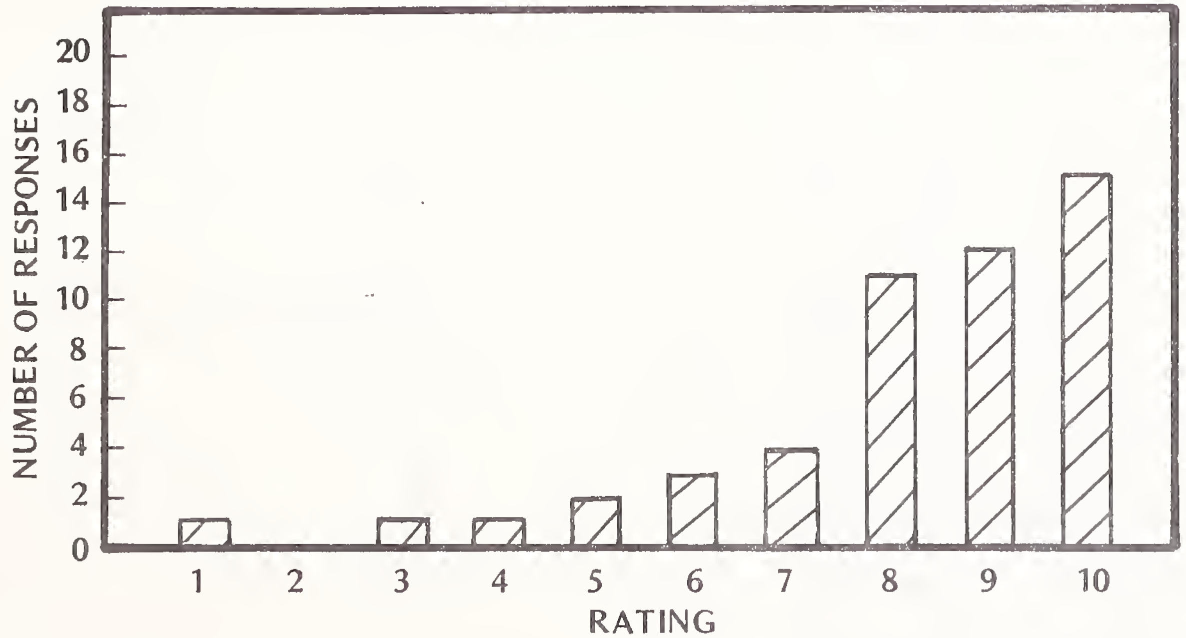
MARKET FORECAST OF SALES VALUE OF ELECTRONIC CAD/CAM SYSTEMS, SOFTWARE AND SERVICES, 1981-1986 ($ millions)

TYPE OF SYSTEM	1980 BASE YEAR	1981	1982	1983	1984	1985	1986	AAGR 1980-1986 (percent)
Turnkey	$165	$200	$240	$290	$350	$430	$ 520	21%
In-House Equipment	67	100	150	220	330	490	730	49
Remote Computing Services	7	10	10	15	15	20	25	24
Software Products	4	5	7	10	15	20	25	36
Total	$243	$315	$407	$535	$710	$960	$1,300	32%

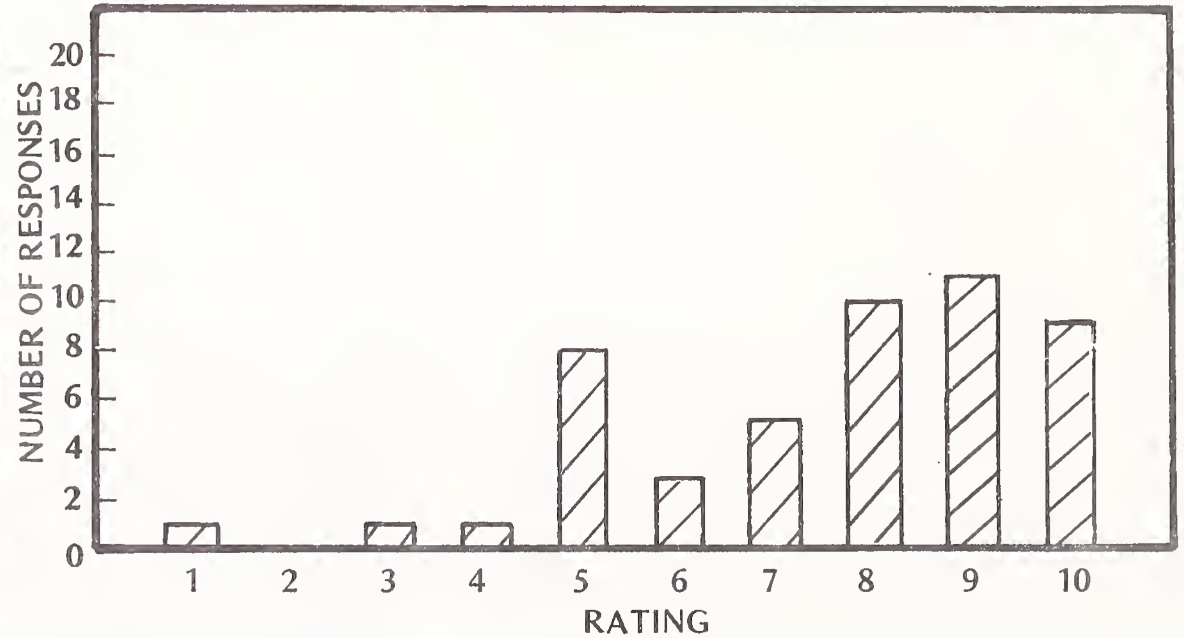
EXHIBIT B-4*

IMPORTANT FACTORS IN THE SELECTION OF SYSTEMS AND VENDORS

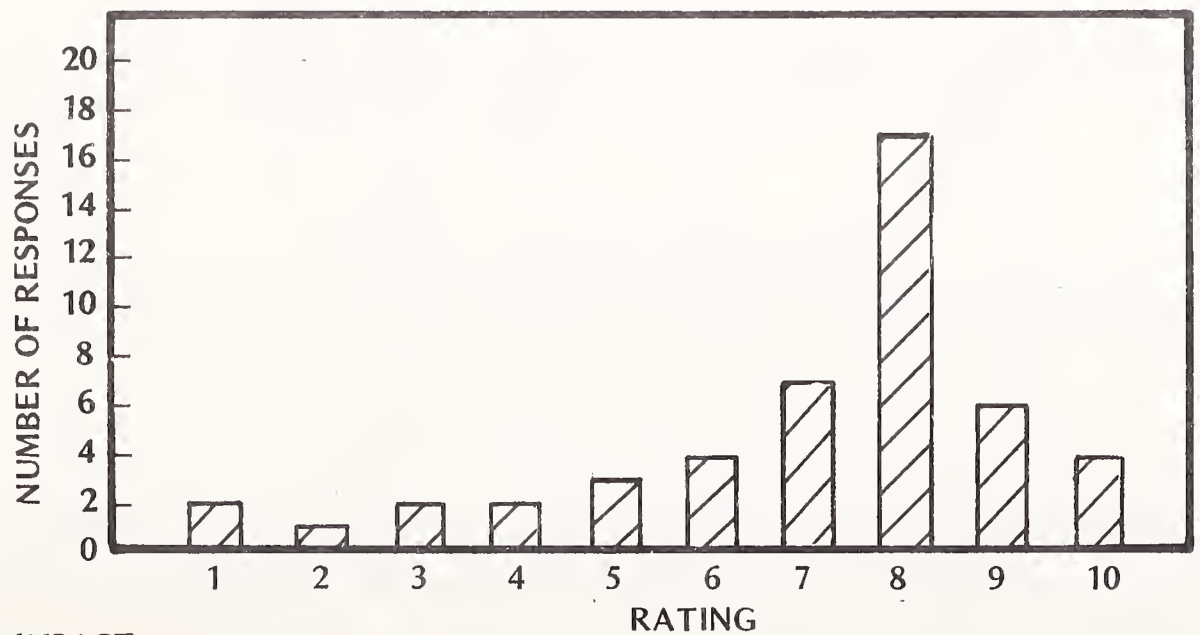
SOFTWARE
MEAN = 8.2



SYSTEMS FLEXIBILITY
MEAN = 7.6



PROCESSING CAPABILITY
MEAN = 7.0



1 = NO IMPACT 10 = MAJOR IMPACT

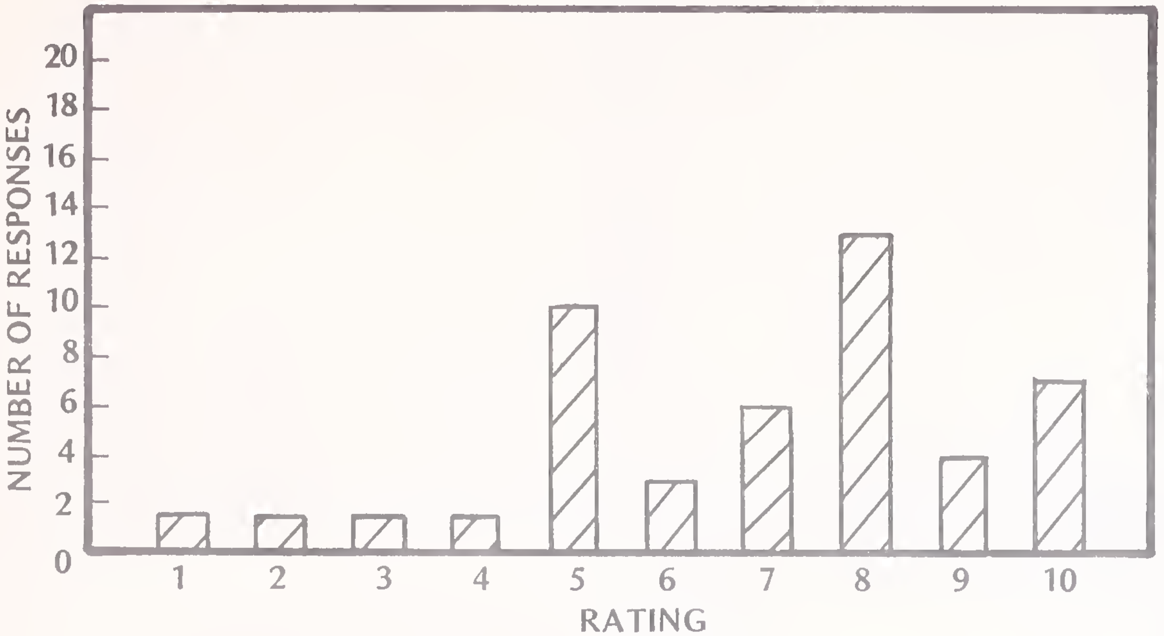
*EXHIBIT II-2 — Detail

Continued

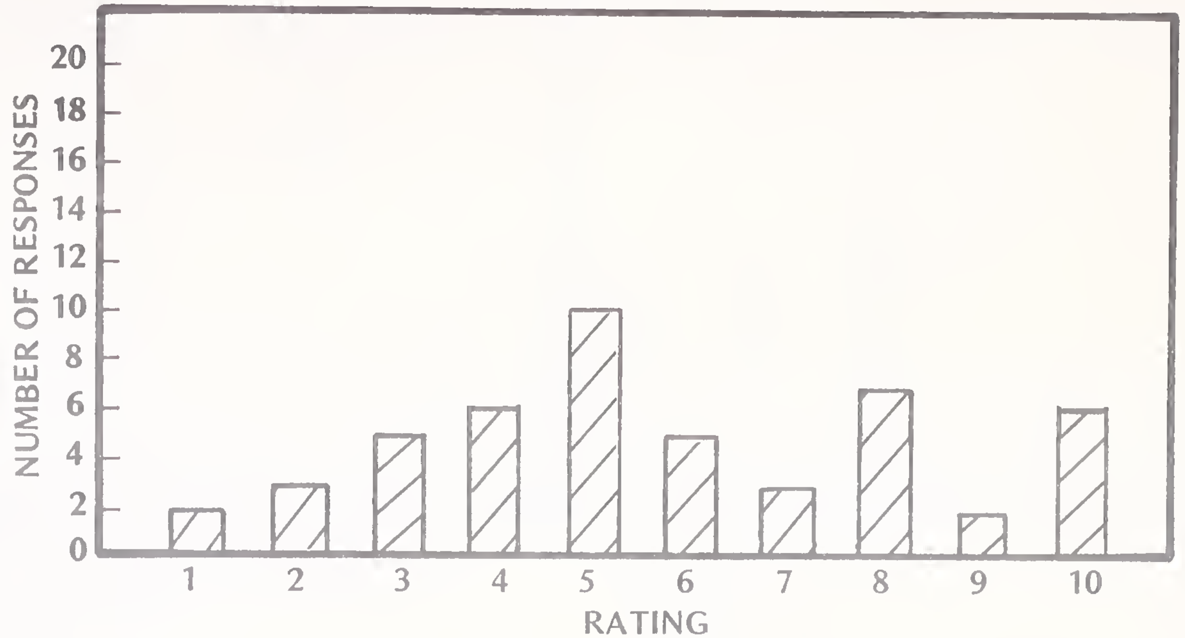
EXHIBIT B-4 (Cont.)*

IMPORTANT FACTORS IN THE SELECTION OF SYSTEMS AND VENDORS

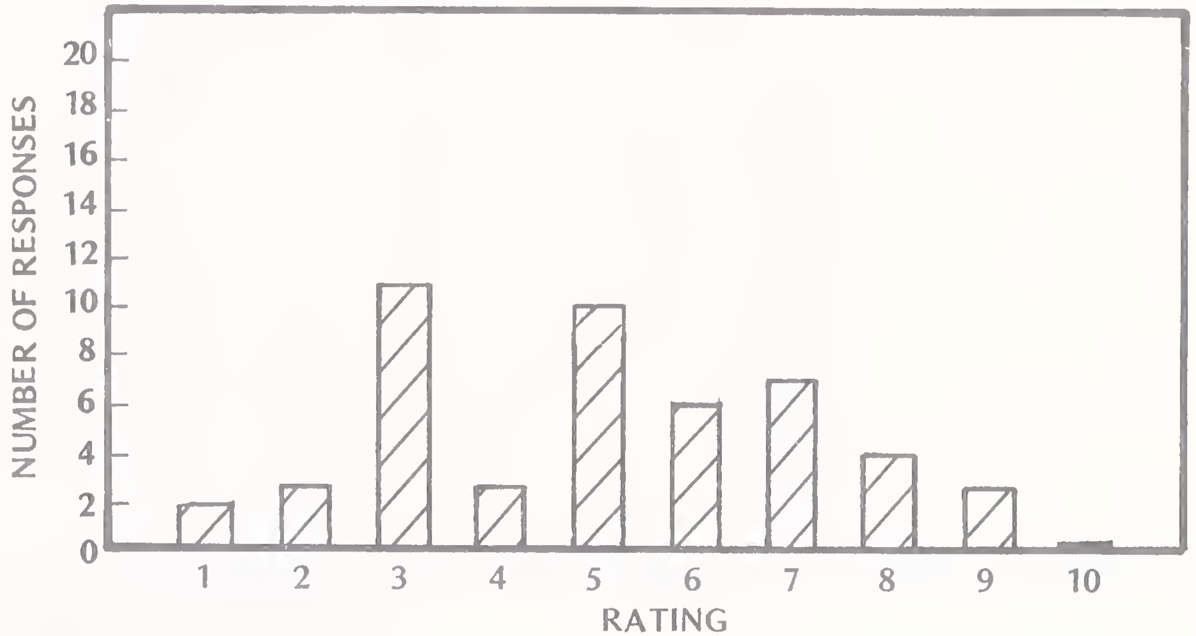
FUTURE ENHANCEMENTS
MEAN = 7.0



ACCESS TO DATA BASES
MEAN = 5.8



COST
MEAN = 5.0

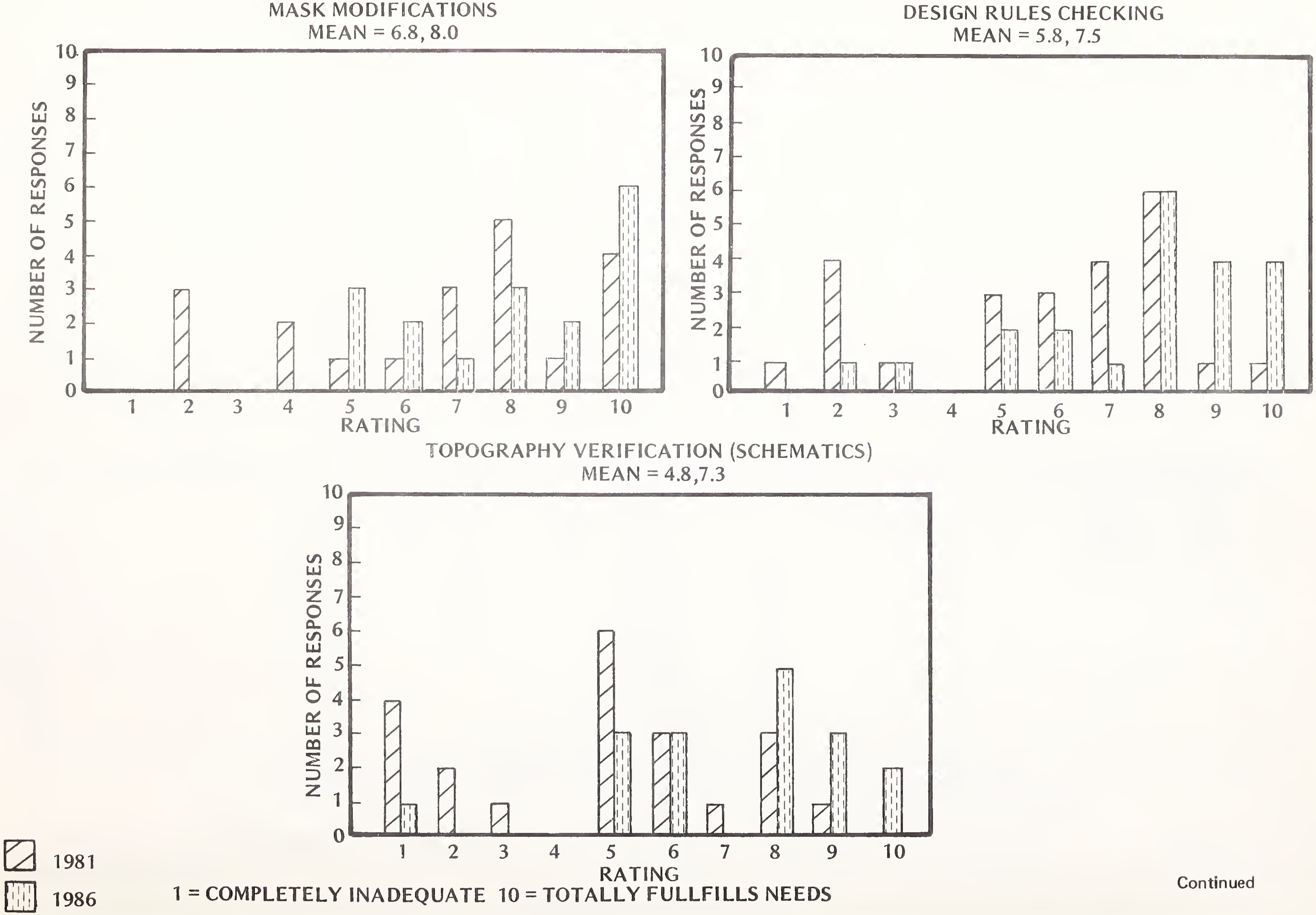


1 = NO IMPACT 10 = MAJOR IMPACT

*EXHIBIT II-2 – Detail

EXHIBIT B-5*

ADEQUACY OF INDIVIDUAL FEATURES OF CAD/CAM SYSTEMS FOR INTEGRATED CIRCUITS



1 = COMPLETELY INADEQUATE 10 = TOTALLY FULLFILLS NEEDS

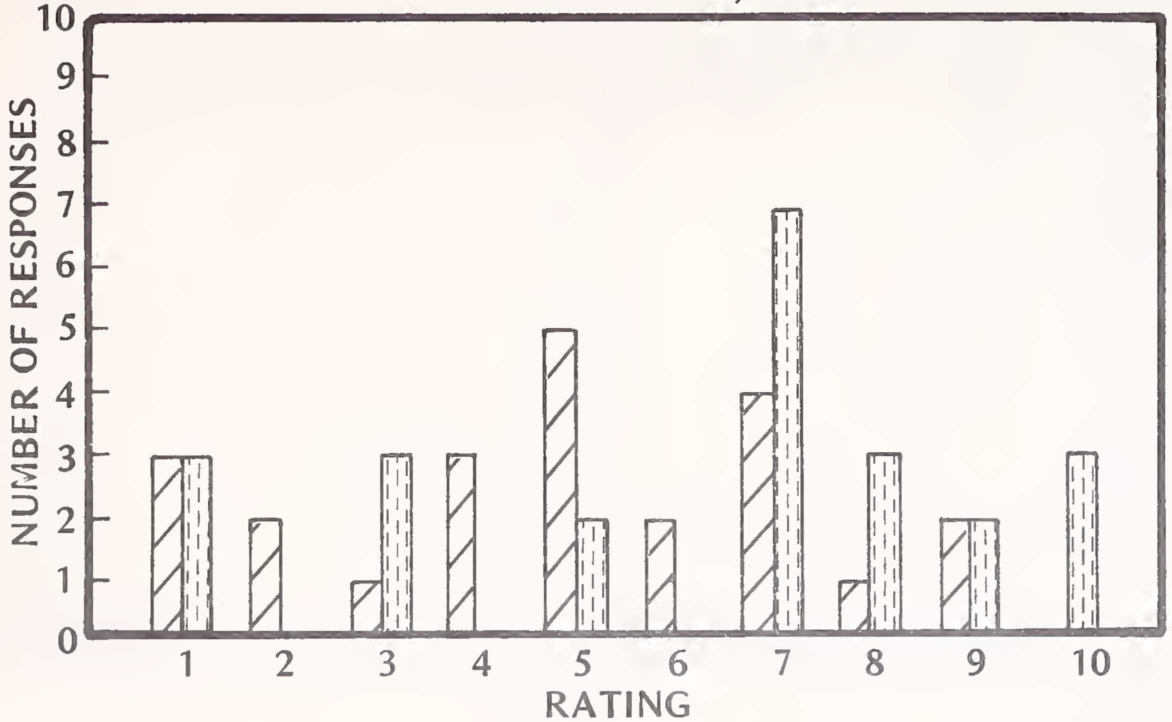
*EXHIBIT IV-7 — Detail

Continued

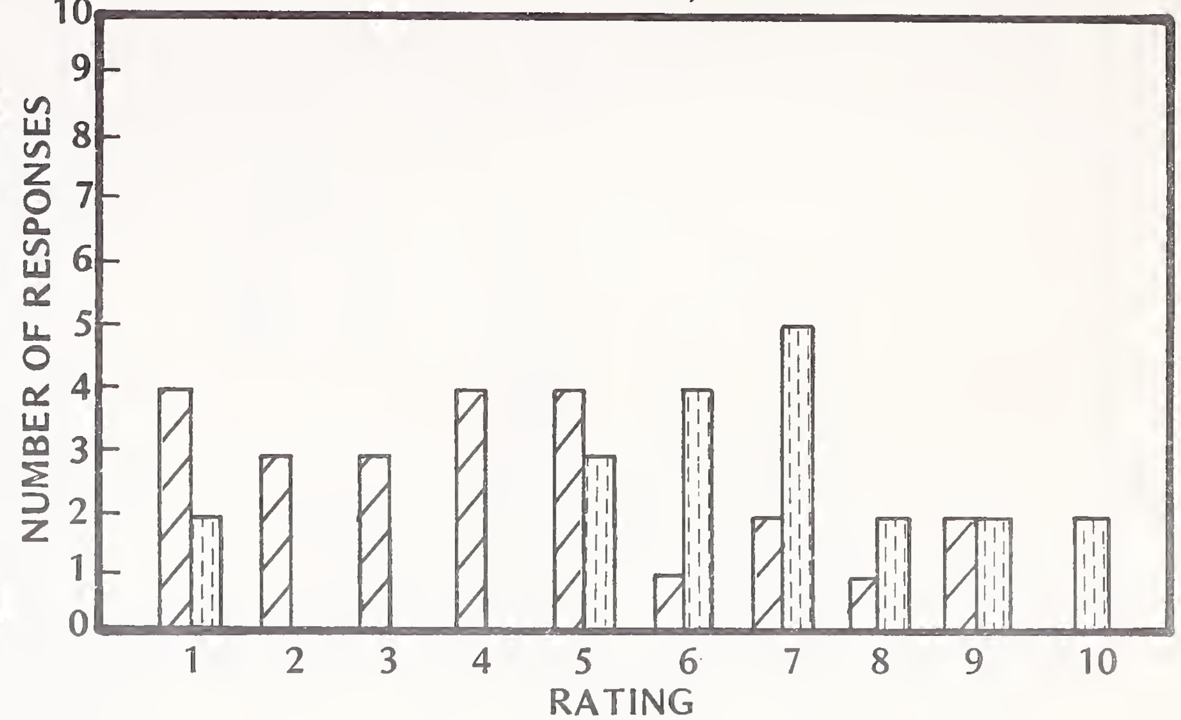
EXHIBIT B-5 (Cont.)*

ADEQUACY OF INDIVIDUAL FEATURES OF CAD/CAM SYSTEMS FOR INTEGRATED CIRCUITS

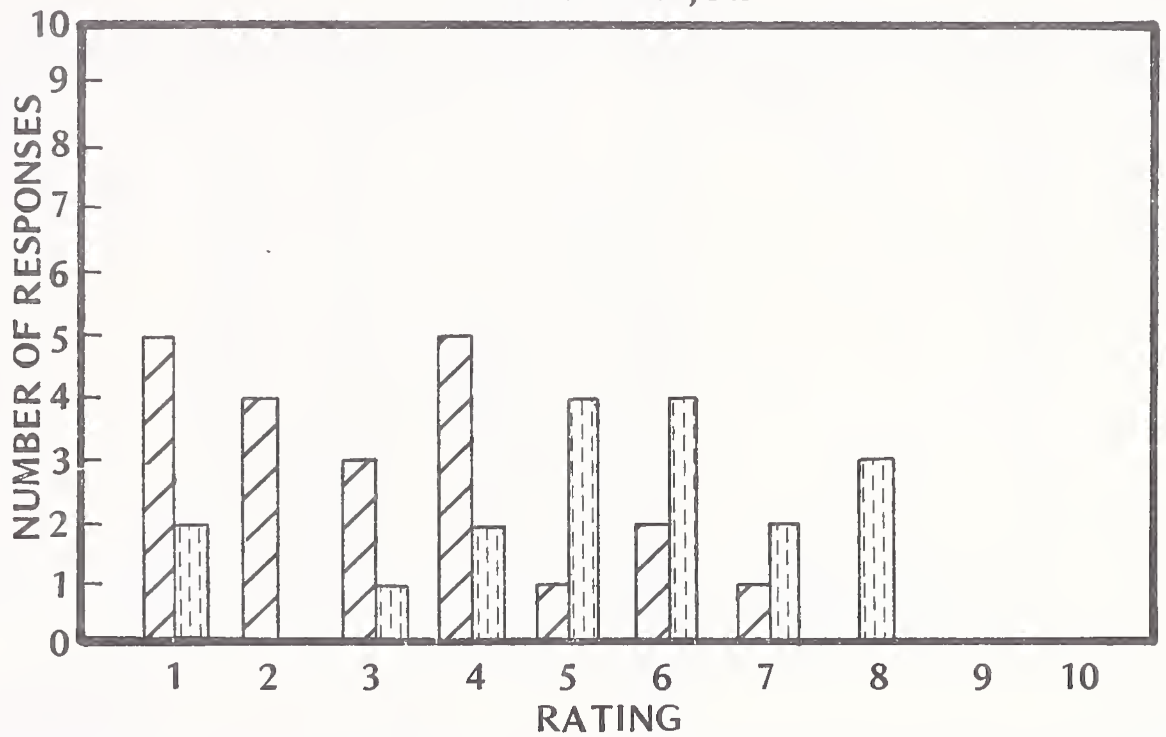
CIRCUIT SIMULATION
MEAN = 5.0, 6.5



FUNCTIONAL AND LOGIC SIMULATION
MEAN = 4.3, 6.5



TESTING
MEAN = 3.1, 5.3

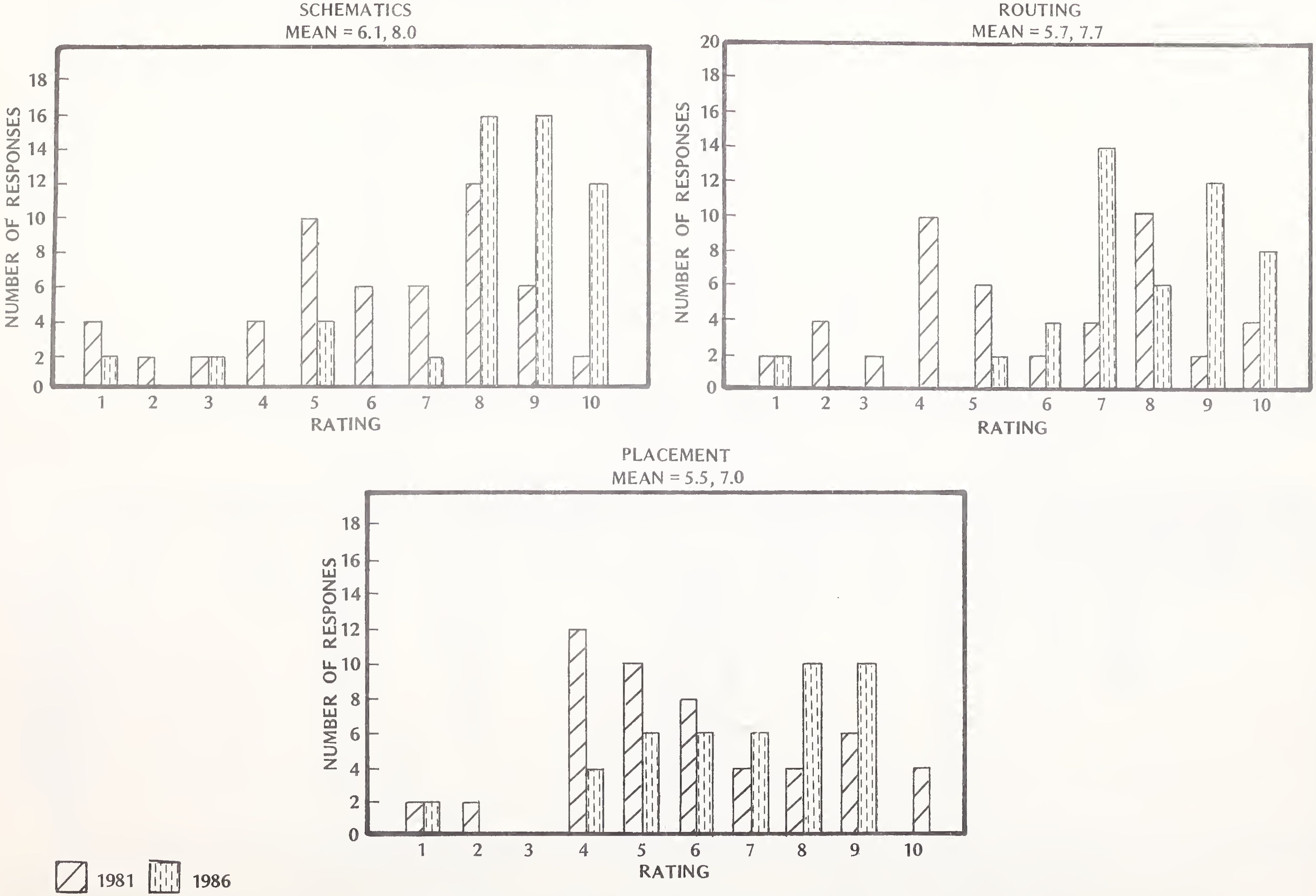


1 = COMPLETELY INADEQUATE 10 = TOTALLY FULLFILLS NEEDS

*EXHIBIT IV-7 — Detail

EXHIBIT B-6*

ADEQUACY OF INDIVIDUAL FEATURES OF CAD/CAM SYSTEMS FOR PRINTED CIRCUITS



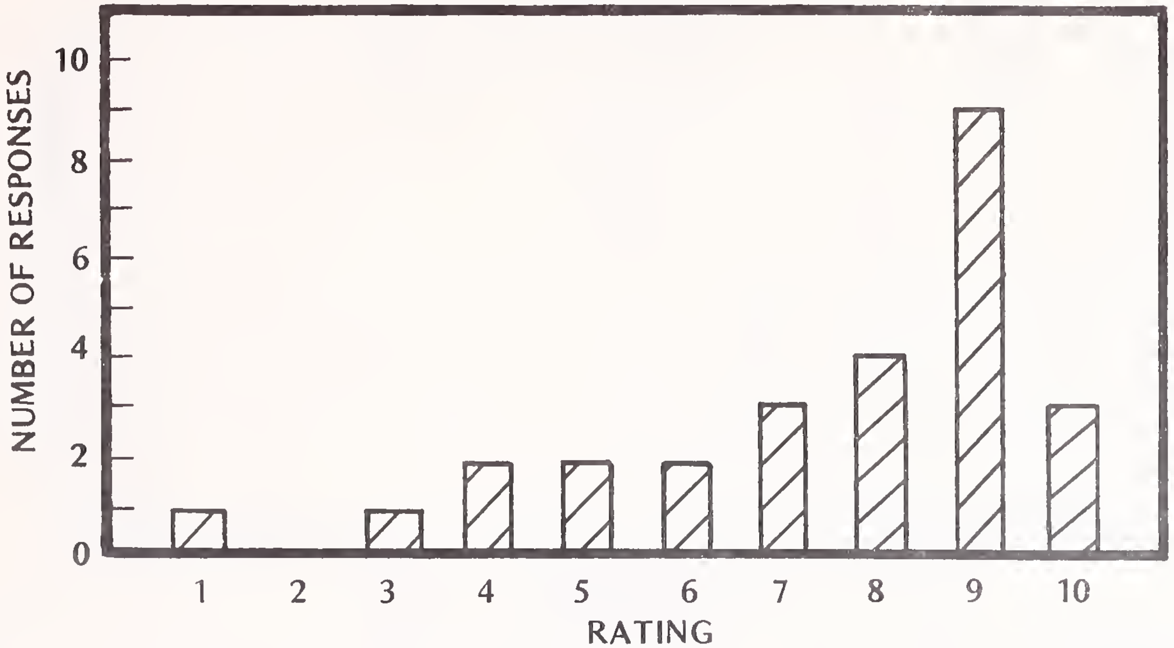
1 = COMPLETELY INADEQUATE 10 = TOTALLY FULFILLS NEEDS

*EXHIBIT IV-8 – Detail

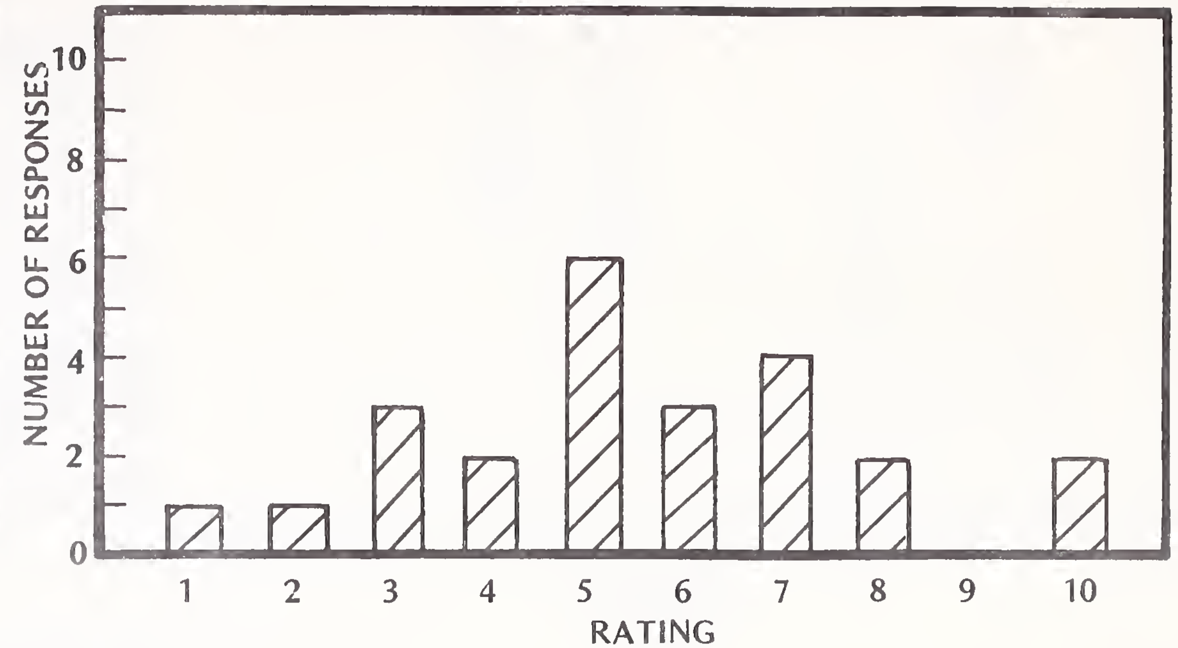
EXHIBIT B-7*

RATINGS OF THE ABILITY OF THE INTEGRATED CIRCUIT CAD VENDORS TO MEET OVERALL USER NEEDS

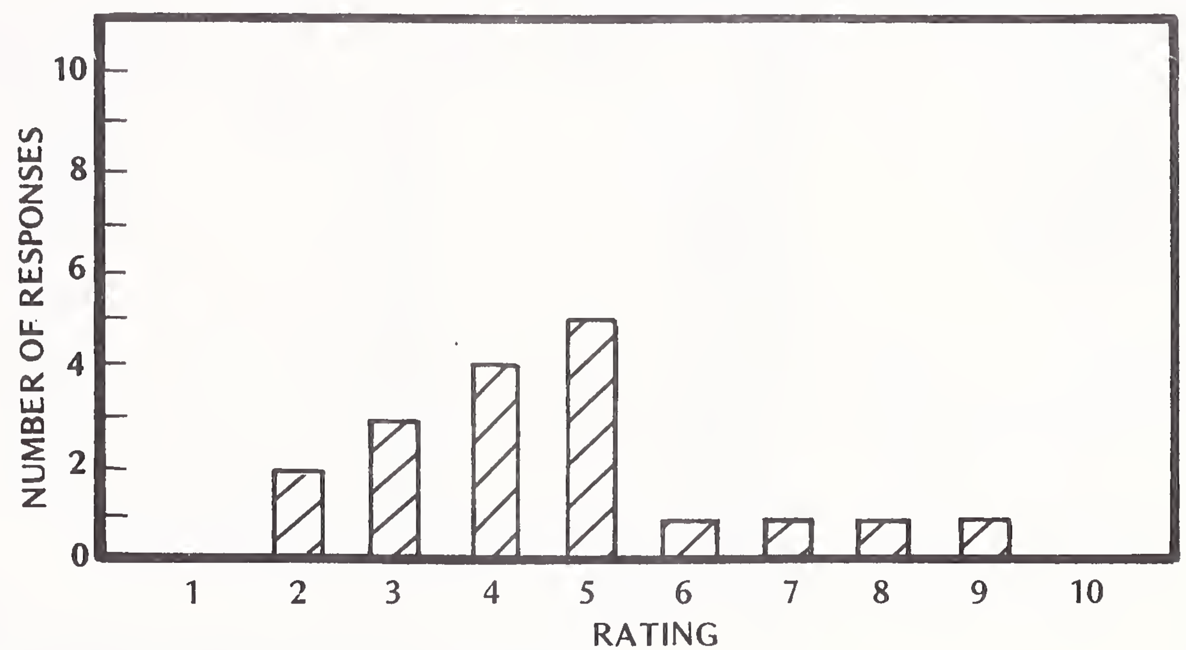
CALMA
MEAN = 7.3



APPLICON
MEAN = 5.5



COMPUTERVISION
MEAN = 4.7



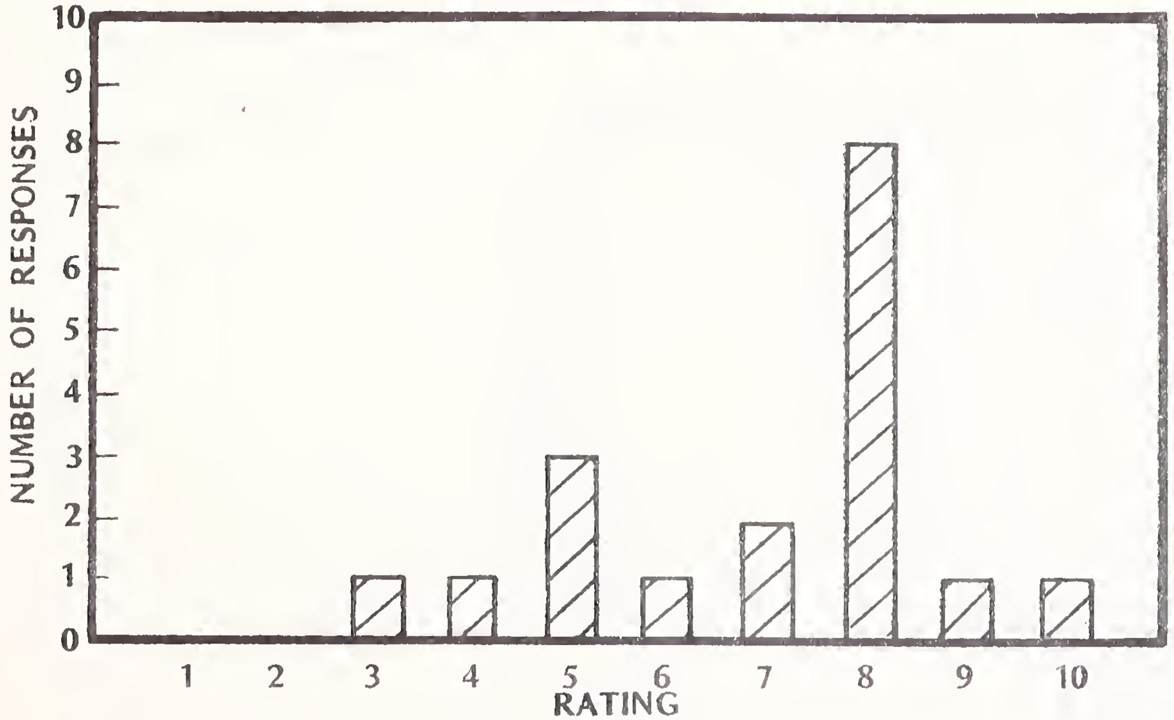
1 = COMPLETELY INADEQUATE 10 = TOTALLY FULFILLS NEEDS

*EXHIBIT IV-11 – Detail

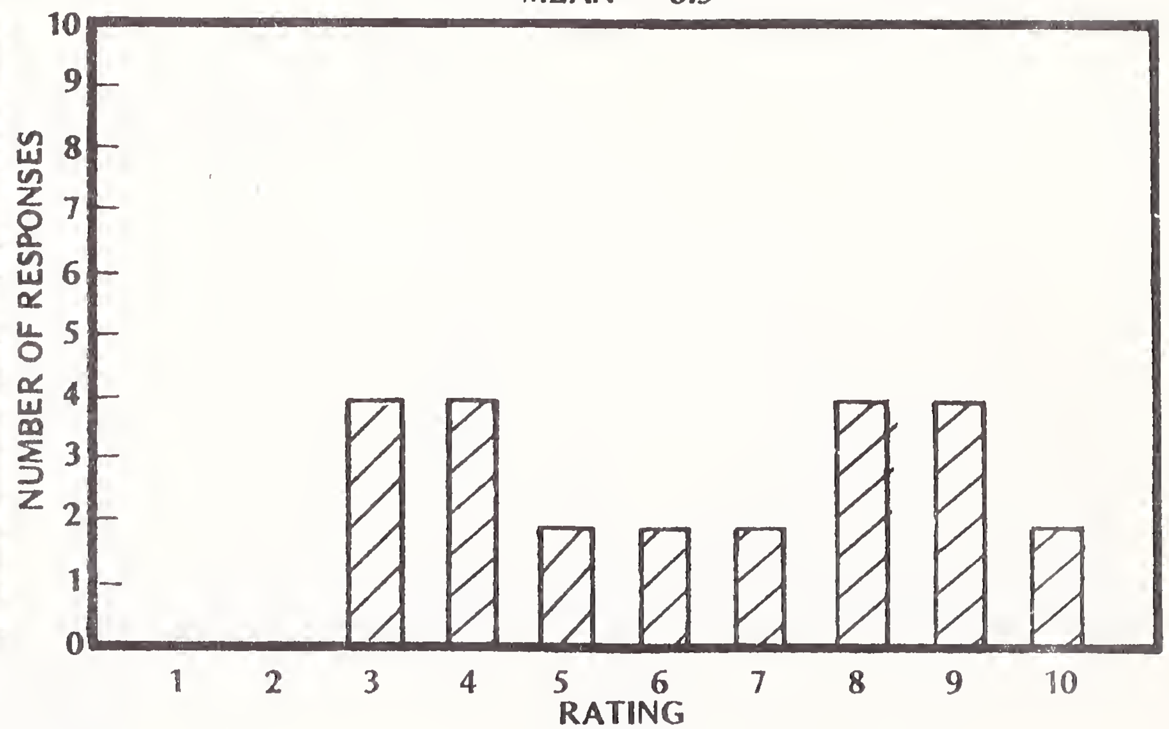
EXHIBIT B-8*

RATINGS OF THE ABILITY OF THE PCB CAD VENDORS TO MEET OVERALL USER NEEDS

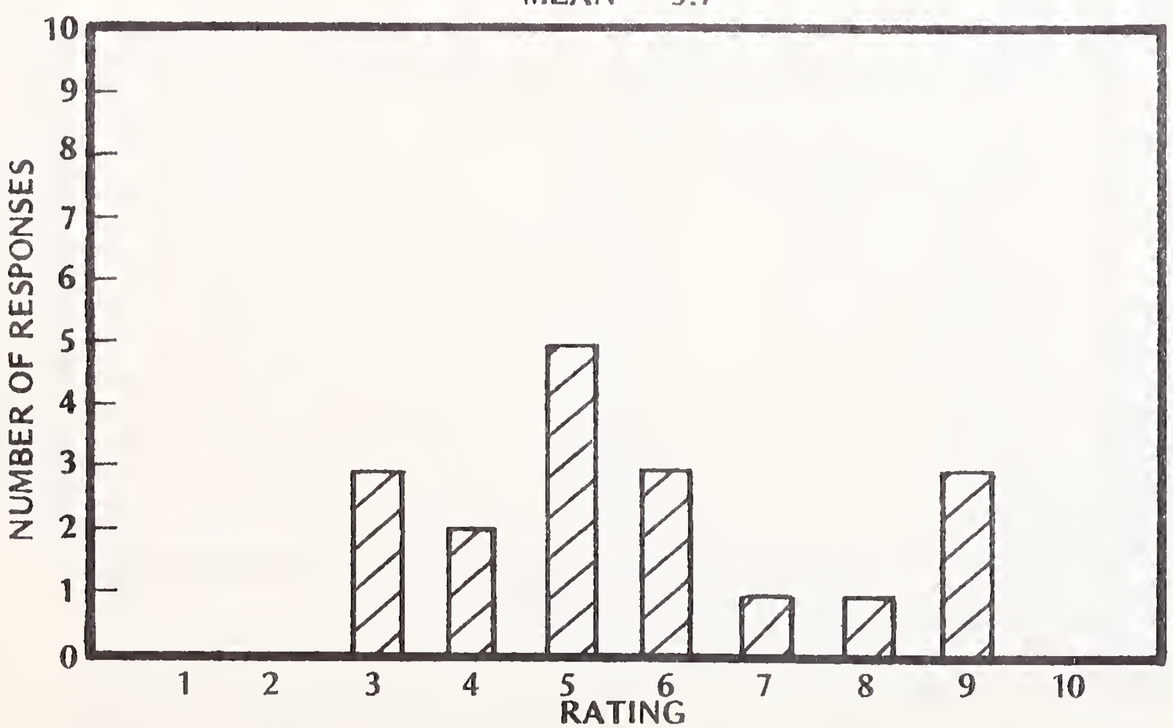
SCIENTIFIC CALCULATIONS INC.
MEAN = 6.9



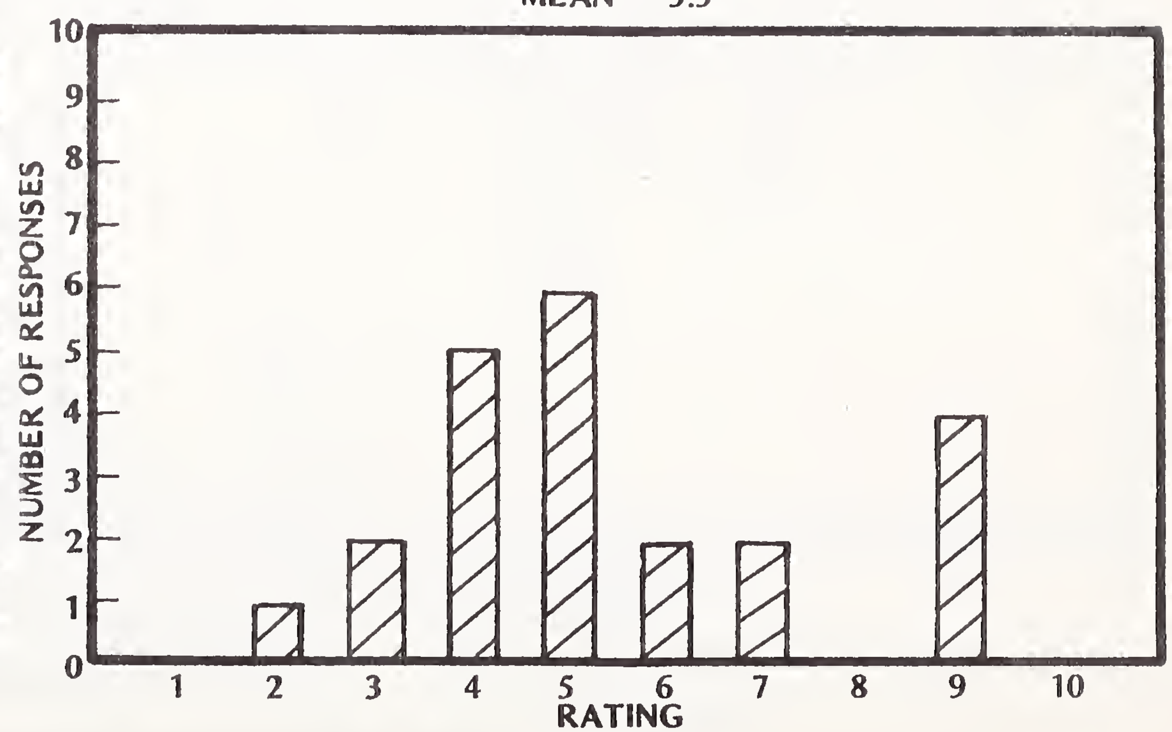
COMPUTERVISION
MEAN = 6.3



REDAC INTERACTIVE GRAPHICS, INC.
MEAN = 5.7



APPLICON
MEAN = 5.5



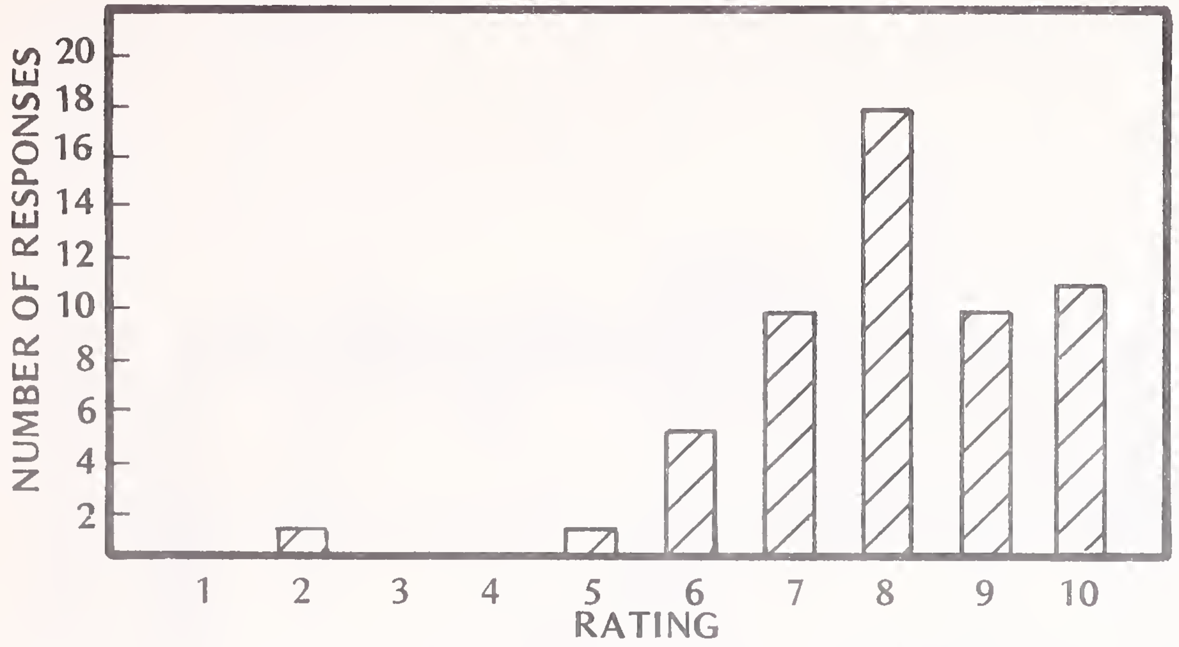
RATING 1 = COMPLETELY INADEQUATE 10 = TOTALLY FULFILLS NEEDS

*EXHIBIT IV-11 – Detail

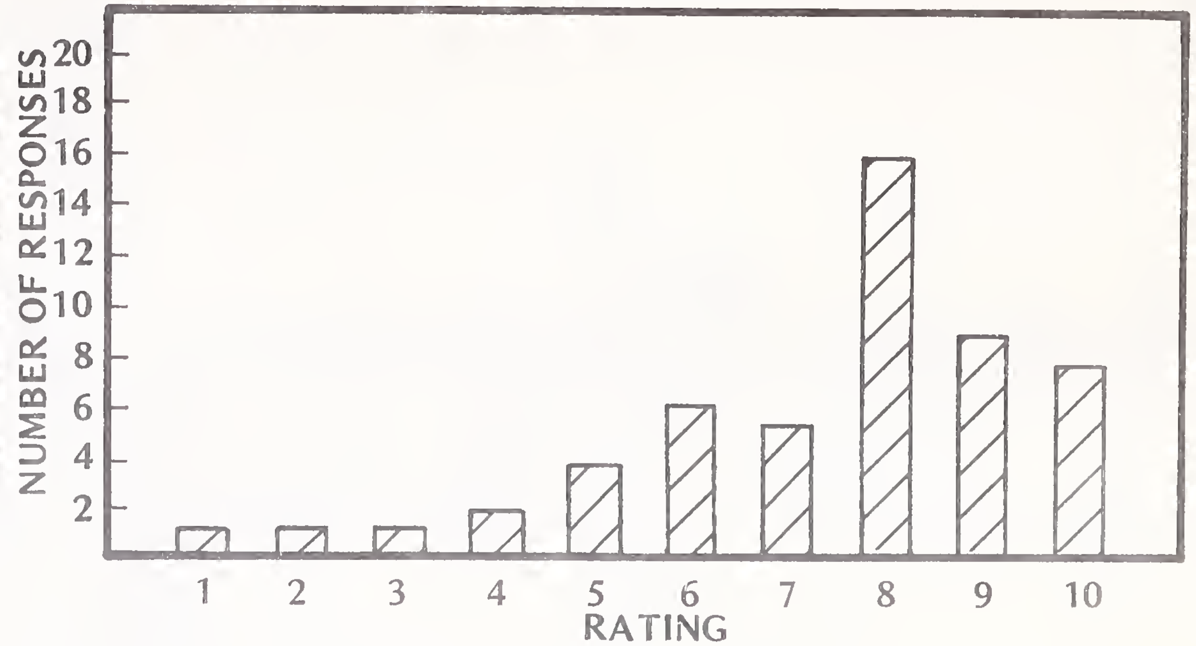
EXHIBIT B-9*

IMPORTANCE OF KEY ISSUES IN COST JUSTIFICATION OF CAD/CAM SYSTEMS

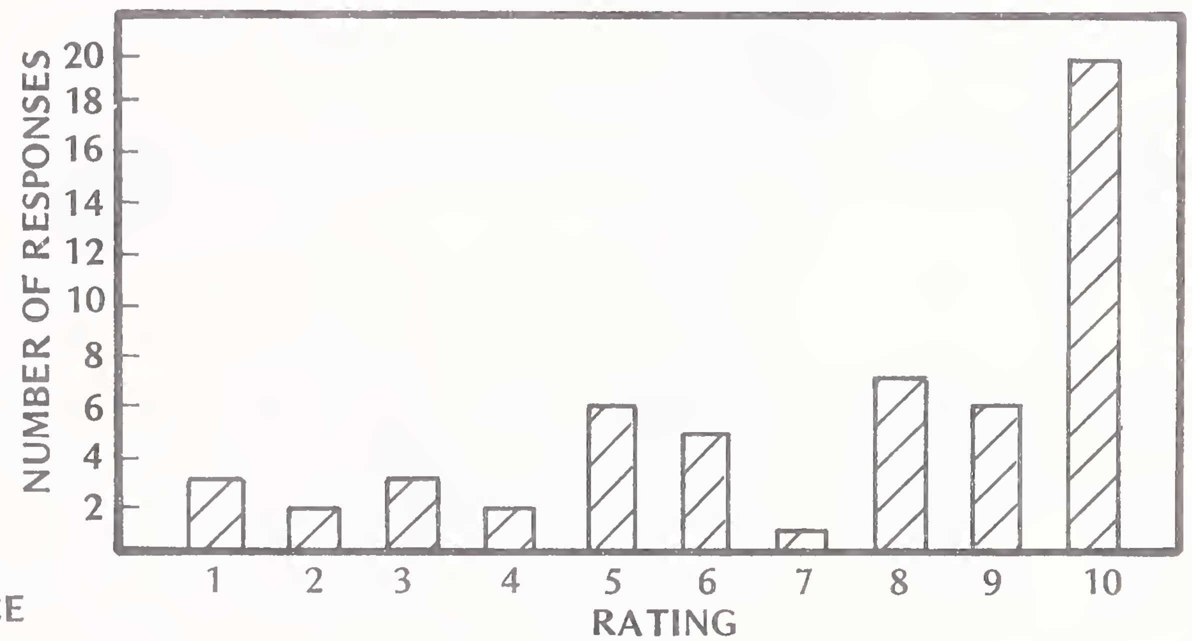
ACHIEVE A MORE COMPLEX PRODUCT
MEAN = 8.1



SHORTENED DESIGN SPAN
MEAN = 7.6



DESIGNS IMPOSSIBLE WITHOUT CAD/CAM
MEAN = 7.3



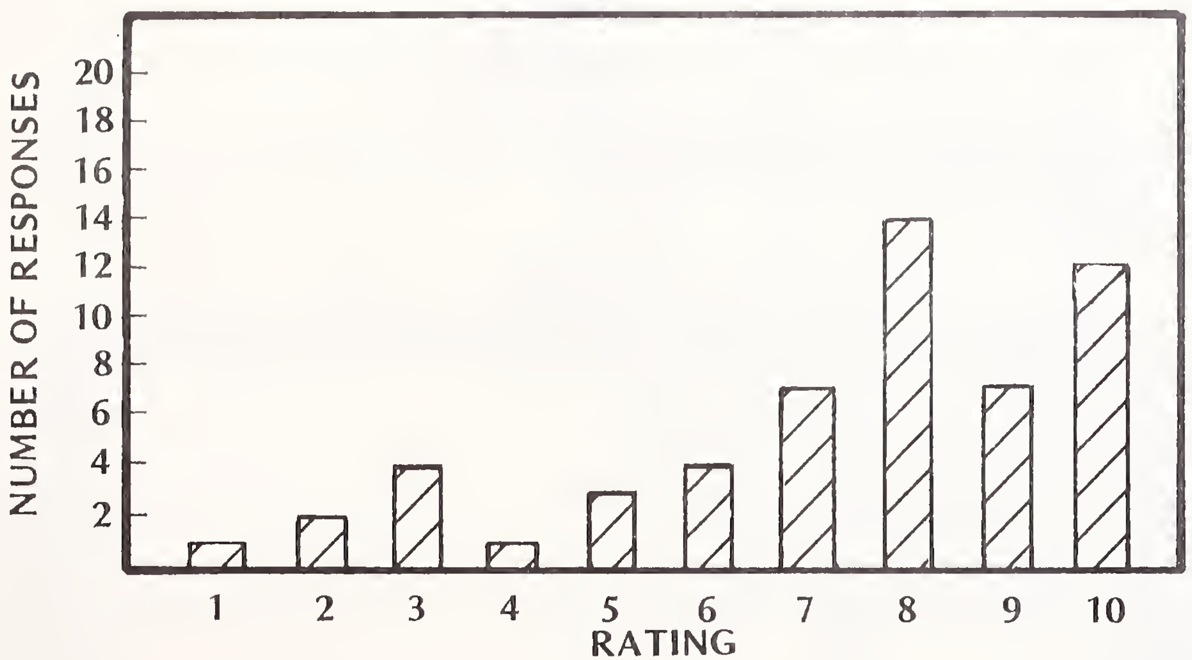
RATING
1 = NO IMPORTANCE
10 = VITAL IMPORTANCE

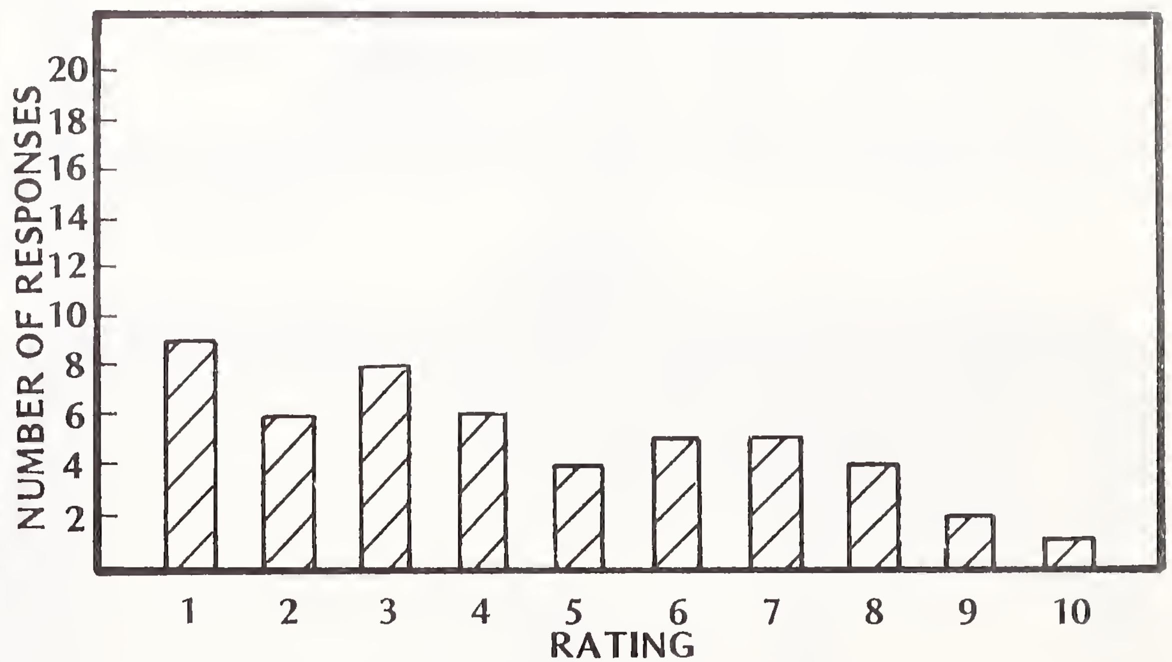
*EXHIBIT V-2 – Detail

Continued

EXHIBIT B-9 (Cont.)*

IMPORTANCE OF KEY ISSUES IN
COST JUSTIFICATION OF CAD/CAM SYSTEMS





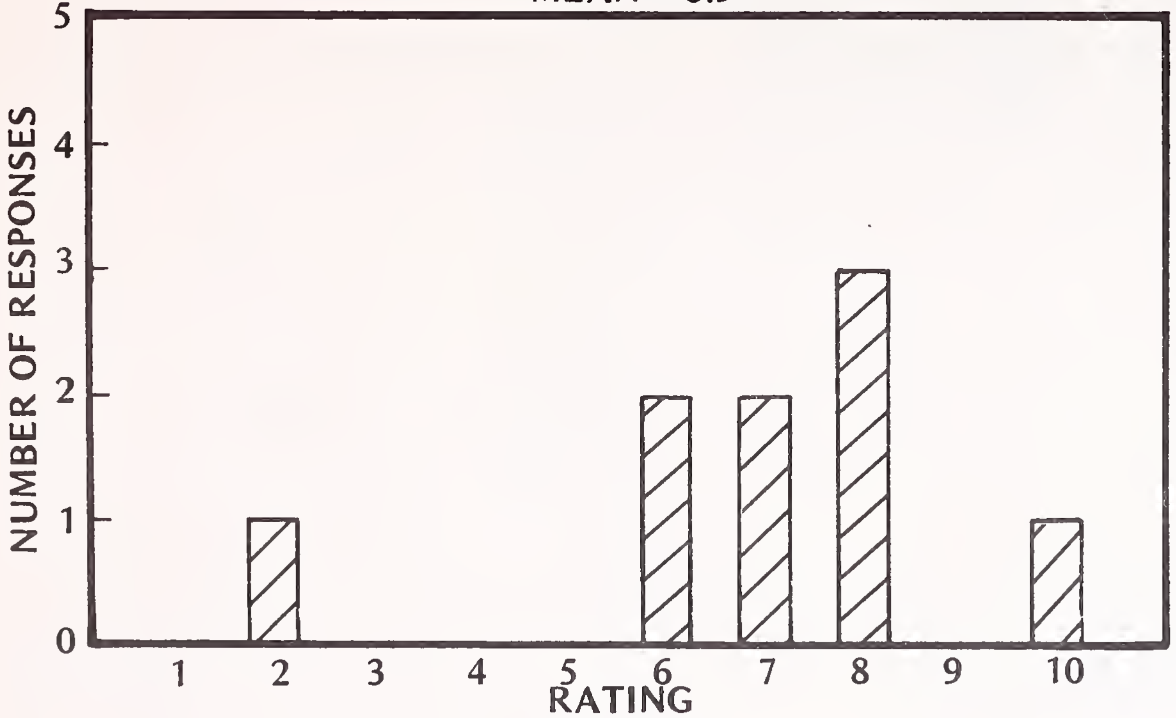
RATING
1 = NO IMPORTANCE
10 = VITAL IMPORTANCE

*EXHIBIT V-2 – Detail

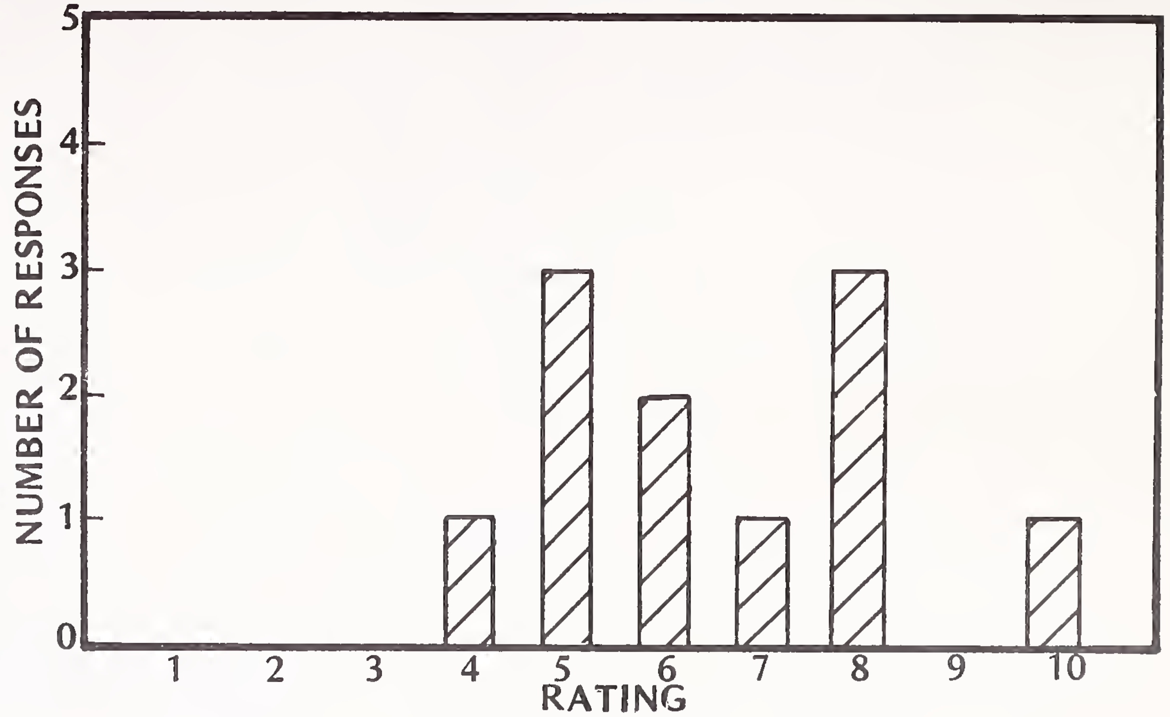
EXHIBIT B-10*

PERCEIVED OBSTACLES TO CAD/CAM INTEGRATION

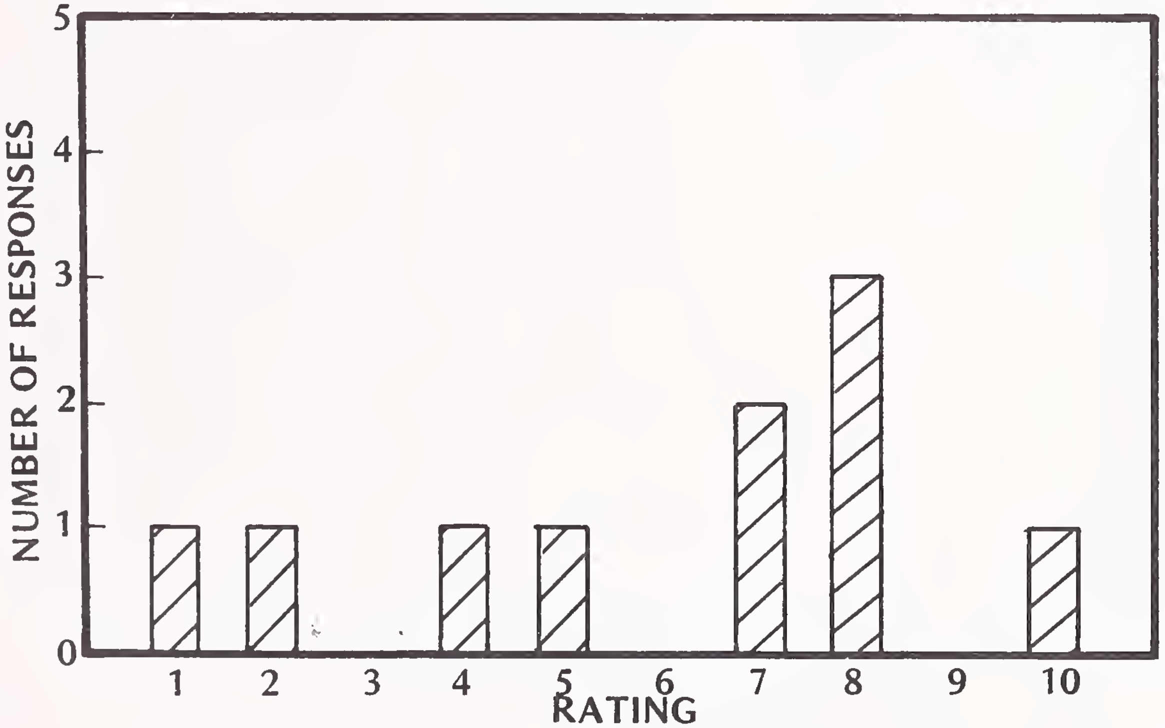
INCOMPATIBLE SYSTEMS COMPONENTS
MEAN = 6.9



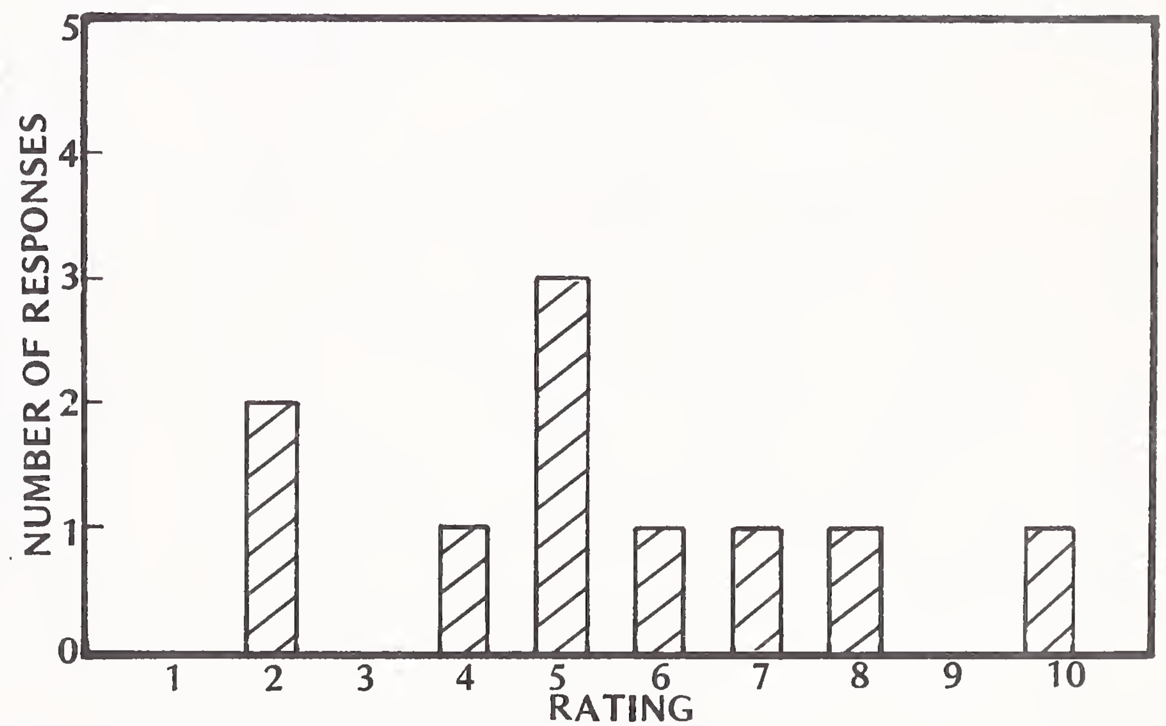
LACK OF STANDARDS
MEAN = 6.5



TOO COMPLEX
MEAN = 6.0



COSTLY IMPLEMENTATION
MEAN = 5.4



1 = NONE 10 = VERY LARGE

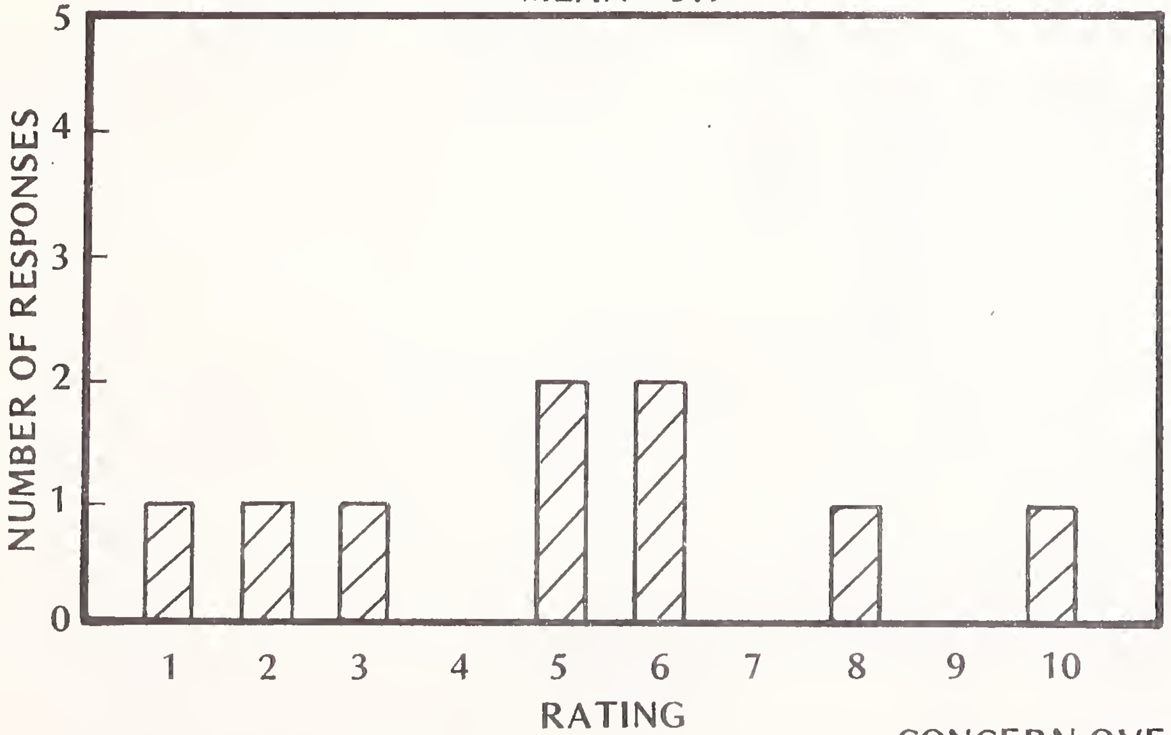
*EXHIBIT VI-4 – Detail

Continued

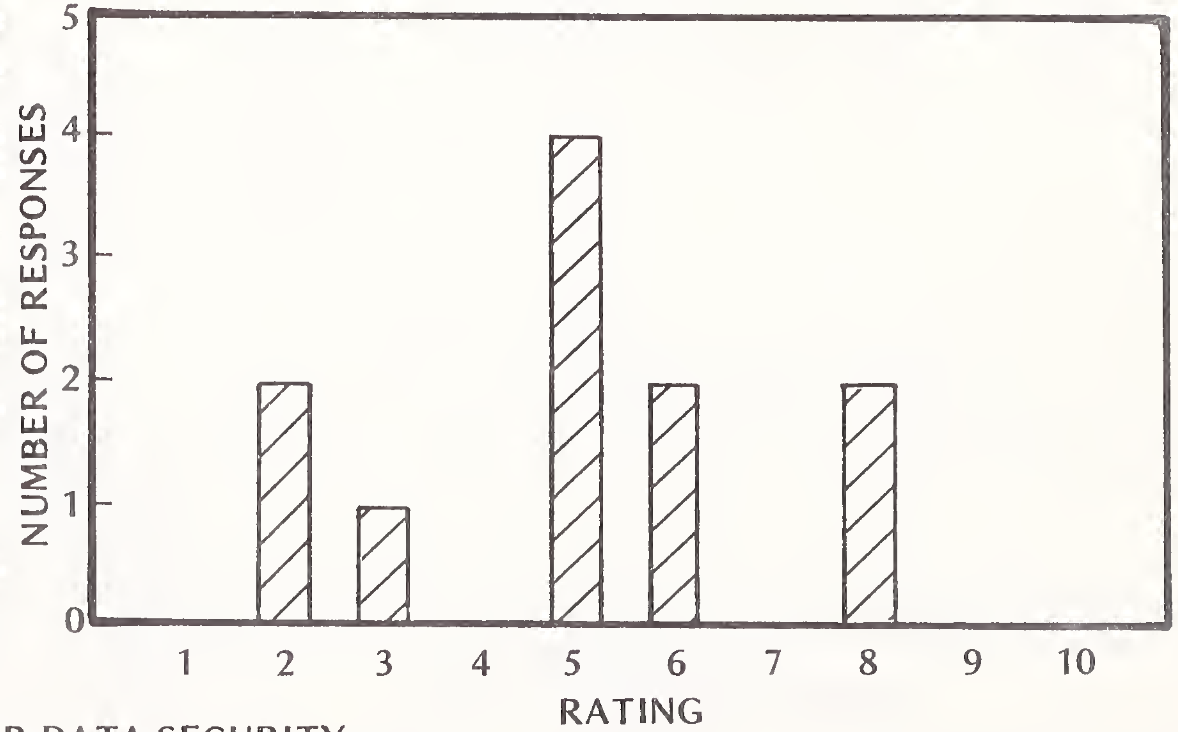
EXHIBIT B-10 (Cont.)*

PERCEIVED OBSTACLES TO CAD/CAM INTEGRATION

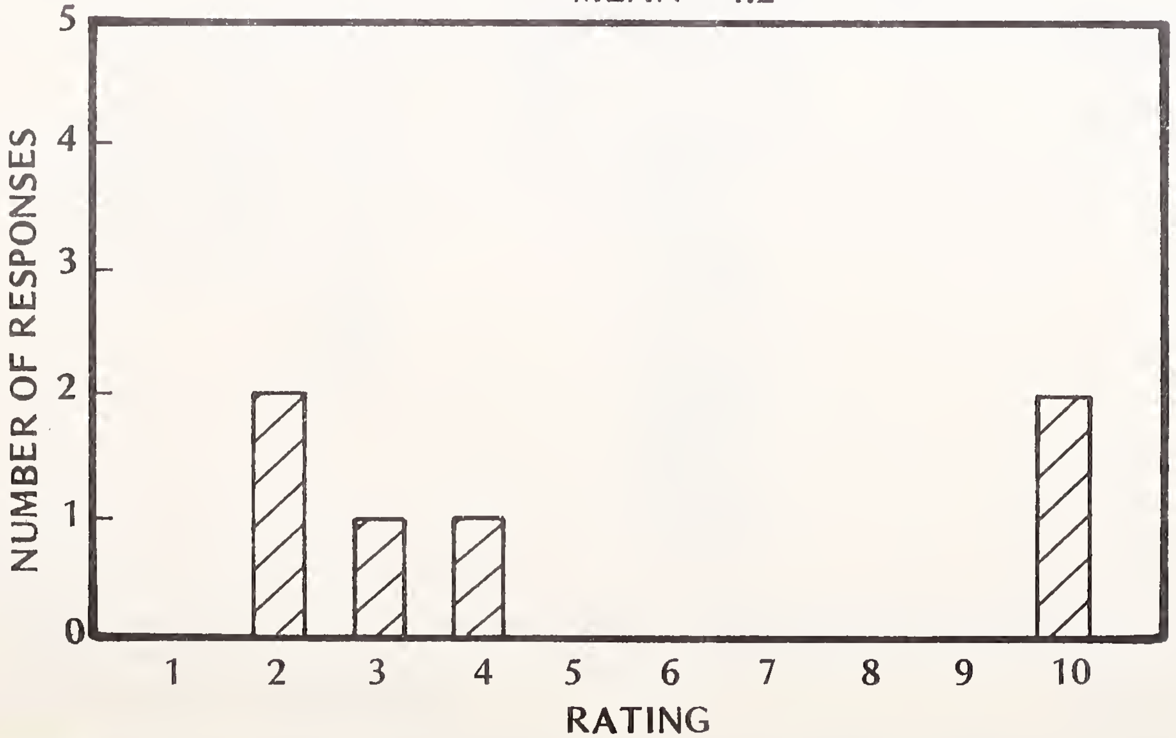
ORGANIZATIONAL CONFLICTS
MEAN = 5.1



BENEFITS NOT PROVEN
MEAN 5.0



CONCERN OVER DATA SECURITY
MEAN = 4.2



1 = NONE 10 = VERY LARGE

*EXHIBIT VI-4 – Detail

APPENDIX C: GLOSSARY OF TERMS

APPENDIX C: GLOSSARY OF TERMS

AEROSPACE (product category). The subgroup of mechanical CAD/CAM users producing aerospace products such as airplanes, missiles, and aircraft engines.

ARTICULATION. Analysis of the movement of connected parts in complex assemblies.

BILL OF MATERIAL (BOM). A listing of all subassemblies, parts, and materials that go into an assembled part showing the quantities of each.

CAD (Computer-Aided Design). Application of computer and graphic technology to engineering, design, and drafting.

CAD/CAM. The integrated application of CAD and CAM.

CALLIGRAPHIC DISPLAY. A cathode ray tube display which writes each vector and character in the sequence of its commands. This display type provides high quality and good dynamics.

CAM. Application of computer and graphic technology to manufacturing engineering, planning, and control.

Computer Output Microfilm (COM). The technology for accepting digital data and recording it on microfilm at high reduction ratios and very high speeds. Useful for recording drawings as well as data.

CORE (SIGGRAPH). A proposed standard for software driving graphic devices, established by SIGGRAPH.

DATA BASE. A set of data records and files structured for a particular operating environment.

DATA BASE MANAGEMENT SYSTEM (DBMS). A software system that allows a user to structure a data base by defining the data, its organization, and the association between data elements. It also includes a data manipulation language (for access, sorting, merging, etc.) and controls for concurrent use (security, request, queueing, etc.). Functions as a common interface to multiple applications.

DATA TABLET. A device consisting of a pad and stylus used to input commands, designate elements, or to digitize drawings for a CAD system.

DISCRETE (product cateogry). The subgroup of mechanical CAD/CAM users producing discrete products such as conveyors, hand tools, electric motors, and air filters.

DISPLAY. A simple graphics terminal or the graphics display component of a more complex terminal.

DISTRIBUTED DATA BASE. A data base which is physically located at multiple sites, with each site having a part of the total data base. The sites are usually linked to a central site as well as having access to each other.

DISTRIBUTED PROCESSING. Multiple computers simultaneously processing elements of a CAD or CAM task.

DYNAMIC MOTION (display). A capability of a display to rapidly and continuously change the viewpoint under operator command.

ENGINEERING/MANUFACTURING DATA BASE. A combined CAD/CAM data base used by both engineering and manufacturing.

FAMILY OF PARTS. A process for defining generic part attributes which, when combined with user-specified parameters, will perform automatic CAD or CAM operations such as drawing, NC programming, or testing and simulation.

FINITE ELEMENT ANALYSIS. As used in this report, this includes all tasks involved in structural analysis using finite element methods: preprocessing or mesh generation, finite element analysis processing, and post-processing.

GKS (Graphic Kernel System). A proposed European standard for interchange of data between CAD systems.

GROUP TECHNOLOGY. The application of classification and coding technology to search a data base for information on similar parts and to apply this to CAD and CAM tasks.

ICAM. U.S. Air Force Integrated Computer Aided Manufacturing program for manufacturing technology.

IGES (Initial Graphics Exchange Specification). A proposed standard for the interchange of data between CAD systems. Developed by the National Bureau of Standards under contract from the ICAM program.

INTELLIGENT WORKSTATION. A CAD or CAM workstation which performs many tasks internally and independent of the host computer.

IPAD (Integrated Programs for Aerospace Vehicle Design). A NASA program to develop an integrated CAD/CAM system for aerospace applications.

KINEMATICS. Analysis of articulated assemblies.

KINETICS. Analysis of dynamic loads.

LAYERING. A technique to assign geometric and other data to spatially related layers, which can be viewed or plotted independently.

LIGHT PEN. A device used to input commands and to designate elements by pointing at or touching the display.

MANAGEMENT INFORMATION SYSTEM (MIS). A data processing system specifically designed to provide business managers with company, financial, project, or program data.

MASS PROPERTIES. Calculation of weights, centers of gravity, and moments of inertia for a closed volume.

MOBILE/TRANSPORTATION (product category). The subgroup of mechanical CAD/CAM users producing products for transportation or similar products, such as automobiles, tractors, and construction machines.

NUMERICAL CONTROL (NC). CAM technology and systems for programming and controlling numerically controlled machines.

NCGA. National Computer Graphics Association.

NC POST PROCESSORS. Computer programs to adopt generic NC commands to drive specific NC machines.

NESTING. Software to automatically or interactively arrange patterns for parts within stock material boundaries.

NETWORKING. The interconnection and control of remotely located systems and devices over communications lines.

RASTER DISPLAY. A CAD display using television technology. Currently has less resolution than Calligraphic, better dynamics than memory tubes, and lower cost.

SHOP FLOOR CONTROL. Control of the progress of each customer order or stock order through the successive operations of its production cycle and the collection of data regarding actual completion results or status.

SIGGRAPH. Special Interest Group on Graphics, an organization within ACM (Association for Computing Machinery).

SOLID MODEL. A computer based representation of a complete, enclosed object or part; the same as a volumetric model.

STORAGE TUBES. A graphics display in which the image is stored on an element behind the viewing screen. Graphics elements can be added to the stored image, but the entire screen must be erased and repainted if elements are deleted. Since this image is not refreshed as in raster or stroke tubes, there is no flicker; however, repaint time for large amounts of data can be significant compared to other technologies.

STROKE REFRESH. A calligraphic display.

SURFACE MODEL. A computer based representation of a surface patch. The surface may be of many types, including ruled, tabulated cylinders, and sculptured.

TRIMMING. The operation of removing the parts of a geometric model which extend past a designated boundary.

TRUE 3-D GEOMETRY. A geometry model for a part which can be viewed from any direction with automatic generation of correct perspective or orthographic views.

TURNKEY CAD. A complete packaged CAD system including all software, computer and other hardware, and user support and training.

VECTOR STROKE. A calligraphic display.

VOLUMETRIC MODEL. The same as a solid model.

WIRE FRAME. A 3-D representation of edges made up of line segments.

APPENDIX D: QUESTIONNAIRES

ELECTRICAL USER OUTLINE

I. GENERAL

II. TECHNOLOGY ISSUES

III. PRODUCTIVITY IMPROVEMENTS

IV. SOFTWARE

V. CAD/CAM INTEGRATION

VI. MAINTENANCE

VII. CAD/CAM SUPPORT OF BUSINESS GRAPHICS

I. GENERAL

1. For the purpose of this study, INPUT defines "CAD" as the utilization of computer aids for graphics, analysis, simulation, modeling requirements, documentation and configuration control in the support of the design function. "CAM" is defined as the utilization of computer aids in the linkage of outputs from design into the manufacturing process through direct control of numerical control equipment, documentation to aid N/C programmers, bills of material, quality control and the mutual exchange of data between manufacturing and design requirements.

2. Is your primary interest in CAD/CAM focused on:

   1e a. _____ Printed circuit, wirewrap, hybrid boards (PCB)

   or

   2e b. _____ Integrated circuits (IC)

   NOTE: Ask only PCB or IC coded specific questions as determined by the above response.

3. What type(s) of CAD systems do you have?

   a. Turnkey systems (Applicon, CV, etc.) _____ 10

   b. Software packages for in-house computer _____ 11

   c. Custom-built system _____ 12

   d. System from a major computer supplier: (IBM, CDC, DEC, PRIME) _____ 13

   e. Remote Computing Services _____ 14

4. How many total workstations are employed?

   _____ Number
   15

5. Are the analysis and processor-intensive functions performed via workstations linked with:

a. An in-house mainframe ____ 16

b. A processor in a turnkey system ____ 17

c. A remote computing company processor ____ 18

d. Distributed processors ____ 19

e. Other (describe) ____ 20

____ ____ 21

Comments: ____

____

6. What vendors are you currently using for CAD/CAM?

a. Turnkey Systems (stand-alone)

	Vendor	Model	System Cost
1.	____ 22	____ 23	$____ 24
2.	____ 25	____ 26	$____ 27
3.	____ 28	____ 29	$____ 30
4.	____ 31	____ 32	$____ 33
5.	____ 34	____ 35	$____ 36

b. In-house systems:

1.	____ 37	____ 38	$____ 39
2.	____ 40	____ 41	$____ 42
3.	____ 43	____ 44	$____ 45
4.	____ 46	____ 47	$____ 48
5.	____ 49	____ 50	$____ 51

6. (Cont.)

c. Remote Computing Services:

	Vendor	Product	Monthly Cost
1.	________ 52	________ 53	$________ 54
2.	________ 55	________ 56	$________ 57
3.	________ 58	________ 59	$________ 60
4.	________ 61	________ 62	$________ 63
5.	________ 64	________ 65	$________ 66

d. Independent Software Packages

	Vendor	Product	System Cost
1.	________ 67	________ 68	$________ 69
2.	________ 70	________ 71	$________ 72
3.	________ 73	________ 74	$________ 75
4.	________ 76	________ 77	$________ 78
5.	________ 79	________ 80	$________ 81

7. Please rate the following factors in terms of their impact on your system selection decision. Rate (on a scale of 1 to 10, where 10 is major impact, and 1 is no impact)

FACTOR	TURNKEY SYSTEMS	IN-HOUSE SYSTEMS	REMOTE COMPUTING SERVICES	INDEPENDENT SOFTWARE PACKAGES
a) Cost	82	83	84	85
b) Processing Capability	86	87	88	89
c) Software	90	91	92	93
d) System Flexibility	94	95	96	97
e) Access to data bases	98	99	100	101
f) Future enhancements	102	103	104	105
g) Other ______ 106	107	108	109	110
h) Other ______ 111	112	113	114	115
i) Other ______ 116	117	118	119	120

Comments: ____________________

____

____

8. Please rate the following vendors with respect to their capability to meet your overall needs, including system capability, enhancements, maintenance, costs, etc. Please rate on a scale of 1 to 10, where 10 is totally fulfilling requirements and 1 is woefully inadequate.

PCB a.

VENDOR	RATING
1. Scientific Calculations, Inc. - SCI-CARDS	3e
2. Bell Northern Research, Ltd. - CPS/COPES	4e
3. Redac Interactive Graphics, Inc. - mini PCB designer	5e
4. Automated Systems, Inc. - PRANCE	6e
5. Computervision - AUTOROUTE	7e
6. CALMA - CARDS	8e
7. Applicon - IMAGE	9e
8. MARK REVEL - AUTOMATE 80	10e
9. Vectron Graphics Systems, Inc.	11e
10. Control Data Corporation - AIDS	12e
11. Other ______________________	13e

8. (cont.)

I.C. a.

VENDOR		RATING
1. Applicon	14e	
2. Calma	15e	
3. Computervision	16e	
4. Hewlett Packard	17e	
5. Control Data Corporation	18e	
6. Other ______________	19e	
7. Other ______________	20e	
8. Other ______________	21e	
9. Other ______________	22e	

Comments: ____

____

____

9.a. Please rate your total CAD/CAM installation in terms of it meeting your expectations at the time of purchase (on a scale of 1 - 10)

1 - 10

1 = totally fails to meet expectations

5 = equals expectations

10 = far exceeds expectations

Rating ______ 159

b. Explain all scores of 4 or less: ______________________

____

____

c. If you were to start over again today, would you buy from the same vendor(s)?

Yes _____ No _____ 160

d. If "no", why not? ______________________

____

10. Please rate the importance of the following benefits of CAD in cost justifying the system. Rate on a scale of 1 to 10, where 1 is not important and 10 is of vital importance.

Benefit	Rating
a. Productivity improvement due to cost savings.	______ 161
b. Design quality (better product)	______ 162
c. Designs cannot be done without CAD/CAM	______ 163
d. More efficient plant loading	______ 164
e. Manufacturing efficiency	______ 165
f. Employee morale	______ 166
g. Better field maintainability	______ 167

11.a. What are your planned expenditures for external CAD/CAM products and services for the following time periods? ($ in thousands-K or millions-M)

ITEM OF EXPENSE	1981	1982	1983
a) Hardware	168	169	170
b) Software	171	172	173
c) Remote Computing Services	174	175	176
d) Turnkey Systems	177	178	179

b. What is the average cost per workstation for your CAD/CAM system?

$ ______K 1981 (180) $______K 1986 (181)

c. What is the average cost per hour per workstation for use of the system?

1981 1986

______$/hr/workstation (182) ______$/hr/workstation (183)

12. What additional external CAD/CAM purchases for products or services do you expect to make by 1986?

a. Hardware ________________ (184)

b. Software ________________ (185)

c. Remote Computing Services ________________ (186)

d. Turnkey Systems ________________ (187)

e. Other ________________ (188)

13. In your opinion, what will be the average annual growth rate for dollars spent on CAD systems and services in the U.S. between 1981 and 1986?

_____ $ AAGR
189

II. TECHNOLOGY ISSUES

14.a. What display terminal technology best serves your applications needs today and in 1986. Please rate on a scale of 1 to 10, where 10 is far exceeding application needs and 1 is totally inadequate for application needs.

TYPE	RATING	
	1981	1986
STORAGE TUBE	___ 190	___ 191
REFRESH:		
VECTOR STROKE (Calligraphic)	___ 192	___ 193
RASTER SCAN	___ 194	___ 195
HYBRID	___ 196	___ 197

b. In rating the types of display, considering the ability of the display to meet your application needs, how important are memory requirements? Please rate on a scale of 1 to 10, where 10 is very important and 1 is not a consideration at all.

	1981	1986
Rating	___ 198	___ 199

c. How important is price in the decision to select a particular display technology?

	1981	1986
Rating	___ 200	___ 201

d. What major changes in display terminals do you expect over the next 5 years, and why will the changes come about?

____
202

____

____

15. IMPORTANCE OF COLOR

a. Are color displays a requirement?

1981 _____ Yes _____ No 203

1986 _____ Yes _____ No 204

Why? ______________________________
205

____

____

b. On a scale of 1 - 10, how important is color to your application needs? (1 = no requirement, 10 is absolutely essential)

	Rating
1981	_____ 206
1986	_____ 207

Comments: ______________________________
208

____

____

16. What is the CAD workstation display resolution of your present system?

_____ 209 by _____ 210

_____ 211 by _____ 212

_____ 213 by _____ 214

17. RESPONSE TIMES

a. What response times are you presently experiencing on your present system?

_____ Seconds
215

b. Is this adequate?

_____ Yes _____ No 216

c. If no, what are your requirements?

_____ Seconds
217

d. Comments: _______________
218

PCB 18. What is the adequacy of CAD systems for board design, now and in 1986? Please rate the systems overall and their individual features. Rate on a scale of 1 to 10, where 10 is completely adequate and 1 is woefully inadequate.

FEATURE	RATING 1981	RATING 1986
a. SCHEMATICS	23e_____	24e_____
b. PLACEMENT	25e_____	26e_____
c. ROUTING	27e_____	28e_____
d. OTHER 29e_____	30e_____	31e_____
e. OVERALL	_____	_____

Comments: 32e _______________

PCB 19. Please rate the importance of the following features of CAD systems for board design. Rate on a scale of 1 to 10, where 10 is of critical importance and 1 is not required.

FEATURE	RATING 1981	RATING 1986
a. Interactive graphics	7.8 (33e)	8.3 (34e)
b. Alphanumeric I/O for schematic capture and update	6.5 (35e)	7.4 (36e)
c. Input data checking and error recovery	7.0 (37e)	7.9 (38e)
d. Quick plot capability	6.7 (39e)	7.8 (40e)
e. High quality plots	7.3 (41e)	8.4 (42e)

PCB 20. What are the importance of the following libraries?

FEATURE	RATING 1981	RATING 1986
a. Schematic symbol library	43e 8.5	44e 9.1
b. Component parts library	45e	46e
c. Mechanical shape library	47e	48e
d. Component outline library	49e	50e
e. Hybrid chip component library	51e	52e
f. Circuit and logic simulation library	53e	54e

M 42

CATALOG NO. XCAD

PCB 21. Do you require:

FEATURE		YES	NO	HOW MANY
a. Multiple data layers	55e	77 93%	2	56e [illegible]
b. Multiple sheet drawings	57e	75 97%	1	58e 37.4 11.3

Comments: 59e ______________________________

____

____

PCB 22. For PCB design, rate the desireability of the following features. Rate on a scale of 1 to 10, where 10 is vital and 1 is un-important.

FEATURES	RATING	
	1981	1986
a. Automatic component placement to gate level	60e 7.2	61e 8.7
b. Automatic routing of 2 sided and multilayer boards	62e 8.0	63e 9.1
c. Output to drive a photo plotter	64e 8.6	65e 8.6
d. Logic vs. layout check and reports	66e 7.7	67e 8.8

PCB 23. For wire wrap design, please rate the desireability of the following features.

FEATURE	RATING 1981	RATING 1986
a. Using net list as the basis for wire wrap and multiwire design	68e 7.9	69e 7.9
b. Automatic placement to minimize wire lengths	70e 6.3	71e 6.8
c. Minimize wire changes in design update while maintaining data and design integrity	72e 7.3	73e 7.1
d. Utilities to produce properly formatted N/C, wirewrap and multitape in standard format.	74e 7.1	75e 7.9

I.C. 24. What level of complexity, in terms of number of devices per chip, do you presently require; and what do you project your requirements to be in 1986?

	1981	1986	1990
Number devices per chip (-000)	76e 25	77e 321	78e 500
		n=7	

not stat. sig

I.C. 25. Please rate the adequacy of present CAD/CAM systems, overall and by individual features. Rate on a scale where 10 is completely adequate.

FEATURE	RATING 1981	RATING 1986	RATING 1990
a. Circuit simulation	79e 5.0	80e 6.5	81e 8.0
b. Functional and logic simulation	82e 4.3	83e 6.5	84e 8.0
c. Topography verification (schematics)	85e 4.8	86e 7.3	87e 9.0
d. Design rules checking	88e 5.5	89e 7.5	90e 8.8
e. Testing	91e 3.1	92e 5.3	93e 6.8
f. Mask modifications	94e 6.5	95e 8.0	96e 10
g. Overall	94ee 5.4	95ee 6.0	96ee 8.0

I.C. 26. Do you use a structured design approach?

97e [illegible] Yes ______ No

I.C. 27. Which methodology do you favor? Please rate on a scale of 1 to 10, where 10 is most favored and 1 is least favored.

METHODOLOGY		RATING
a. Standard Cells	98e	6.5
b. STICKS design approach	99e	4.0
c. symbolic layout	100e	5.0
d. Custom design	101e	6.5
e. Gate array	102e	6.5

28. How long does it take to train a new user of the CAD/CAM system?

a. To initial use ________ weeks
245

b. To complete proficiency ________ weeks
245

29. Would lower CAD/CAM system prices enable you to use these systems more extensively?

Yes _____ No _____ 247

Why or why not? ____
248

____

____

30. USE OF CAD

a. Where are your workstations located?

I. Central design facility _____
249

II. Co-located with design groups _____
250

b. Who operates CAD?

I. Specialist _____
251

II. Engineer _____
252

III. PRODUCTIVITY IMPROVEMENTS

31. What is the importance of the following benefits attributable to CAD/CAM. Please rate on a scale of 1 to 10 and indicate the degree of improvement attained.

BENEFIT		RATING	IMPROVEMENT FACTOR - TIMES
a. Reduced design labor	103e		104e
b. Less computer time	105e		106e
c. Shortened design span	107e		108e
d. Achieve more complex product	109e		110e
e. Better product performance	111e		112e
f. Other ______	113e		114e
g. Other ______	115e		116e
h. Other ______	117e		118e

32.a. Describe how productivity gains associated with CAD/CAM implementation can be measured.

119e ______

______

______

______

b. What has been your general experience with improved productivity?

120e ______

______

______

IV. SOFTWARE

33. ENHANCEMENTS

a. How are systems and applications software enhancements provided for your CAD/CAM system? Please rank in order of importance on a scale of 0 to 1, where 1 is most important.

	Ranking
1. In-house software development group	______ 254
2. Vendor software releases	______ 255
3. Software consulting services	______ 256

b. Do you belong to a users group?

Yes _____ No _____ 267

if yes;

- What is the name of the group?

  ______________________________ name
  268

  Describe the group's goal/function: ____________________

  ____

- How would you rate the overall effectiveness of the group in achieving its goals? (On a scale of 1 to 10, 10 = totally effective, 1 = totally ineffective) ______ rating
  269

c. Are you familiar with the following government programs relating to electronic design and manufacturing, and if you are what impact do you see them having on the industry?

1. Very High Speed Integrated Circuits (VHSIC) Program of the Office of the Under Secretary of Defense for Research and Engineering.

119e _____ Yes _____ No

Impact: 120e ____

____

____

33. (Cont.)

d. Between the National Bureau of Standards' ANSI standard (Initial Graphics Exchange (IGES)), and the SIGGRAPH-CORE standard, which do you feel will become the final standard?

IGES	SIGGRAPH-CORE	COMBI-NATION OF BOTH
☐	☐	☐
278	279	280

Comments: ____________________

34. Please identify which CAD/CAM software packages, and documentation you use (or utilities used in CAD/CAM environment). Rate them on a scale of 1 to 10, where 10 is outstanding and 1 is completely inadequate.

SOFTWARE PACKAGE	USE		RATING APPLICATION	DOCUMENTATION
	YES	NO		
a. "Database Manager" 126e			127e ______	128e
b. NASTRAN (Finite element modeling) 129e			130e ______	131e
c. ISPICE (NCSS Timeshare) 132e			133e ______	134e
d. SPICE 135e			136e ______	137e
e. SCICARDS 138e			139e ______	140e
f. STICKS (Symbolic layout for LSI) 141e			142e ______	143e
g. PRANCE 144e			145e ______	146e
h. TEGAS Logic Sim (digital) 147e			148e ______	149e
i. LOGCAP Logic Sim (digital) 150e			151e ______	152e
j. COMPACT (Circuit Sim) 153e			154e ______	155e
k. Other ______________ 156e			157e ______	158e
l. Other ______________ 159e			160e ______	161e
m. Other ______________			______	
n. Other ______________			______	
o. Other ______________			______	
p. Other ______________			______	

35. OVERALL SOFTWARE EVALUATION

a. Please rate the overall adequancy of your CAD/CAM software today and what it is expected to be in 1986. Rate on a scale of 1 to 10, where 10 is excellent and 1 is very poor.

__________ 1981 (299) __________ 1986 (300)

b. What software requirements of your application are not being met by vendors, or by your in-house software development group?

____
301

V. CAD/CAM INTEGRATION

36. STATUS OF CAD/CAM INTEGRATION

a. How far has industry progressed toward CAD/CAM integration now, and how far do you expect it to be in 1986? Please rate on a scale of 1 to 10, where 10 is completely integrated systems and 1 is no progress at all.

	1981	1986
Rating	_____ 302	_____ 303

b. To your knowledge, what results have actually been obtained towards integrating CAD and CAM?

____
304
____

37. Is there or will there be a trend towards integrating design engineering data bases with:

		1981		1986		
a) production	305	Yes _____	No _____	Yes _____	No _____	306
b) quality control	307	Yes _____	No _____	Yes _____	No _____	308
c) finance	309	Yes _____	No _____	Yes _____	No _____	310
d) marketing	311	Yes _____	No _____	Yes _____	No _____	312
e) purchasing	313	Yes _____	No _____	Yes _____	No _____	314
f) research and development	315	Yes _____	No _____	Yes _____	No _____	316
g) other _____ 317	318	Yes _____	No _____	Yes _____	No _____	319

Why will this design engineering data base (not) take place with other functional data bases?

____
320
____

38. How will the trend towards engineering and manufacturing data base integration change organizational responsibility in:

a) design engineering ______________________________
321
____

b) production planning and control ____________________
322
____

c) factory operations ______________________________
323
____

d) traditional DP functions __________________________
324
____

39. Please rate the following in terms of their being an obstacle to an integrated CAD/CAM data base. Please rate on a scale of 1 to 10, where 10 is a very large obstacle and 1 is no obstacle at all.

lack of standards ____ 325

too much complexity ____ 326

incompatible systems components ____ 327

concern over data securiy ____ 328

costly implementation ____ 329

organizational conflicts ____ 330

benefits not proven ____ 331

other (please specify) ______________________ 332 ____ 333

40. Will distributed data bases for design engineering data and manufacturing operations data be developed for integrated CAD/CAM installations?

1981 Yes ____ No ____ Don't know ____ 334

1986 Yes ____ No ____ Don't know ____ 335

VI. MAINTENANCE

41.a. Is your hardware maintained through:

_____ A monthly maintenance contract $ _____/month
341 342

_____ A time and materials arrangement $ _____/month averaged
343 344

_____ In-house personnel _____ number
345 346

b. Is the software supported through:

_____ A monthly maintenance fee $_____/month
347 348

_____ A time and materials arrangement $ _____/month averaged
349 350

_____ In-house personnel _____ number
351 352

_____ No charge
353

42. How would you rate the overall quality of the maintenance you receive? Please rate on a scale of 1 to 10, where 10 is superior and 1 is completely inadequate.

Hardware _____ Software _____
354 355

If less than 4, comment. (What has the vendor promised to do that he is not doing?)

____

____

____

43. What levels of response are you presently receiving for the following maintenance characteristics?

	Actually Experienced		Minimum Acceptable	
	Hdwre	Sftwre	Hdwre	Sftwre
a. Mean time to respond (hours)	356	357	358	359
b. Mean time to repair (hours)	360	361	362	363
c. MTBF (hours)	354	365	366	367
d. Percent uptime (%)	368	369	370	371

44. What percent of the total purchase decision for future CAD/CAM systems will be based on the quality of maintenance service a vendor provides?

______%
372

VII. CAD/CAM SUPPORT OF BUSINESS GRAPHICS

45. COMPUTER BUSINESS GRAPHICS

a. Please rate the importance of CAD/CAM as the basic capability that allows an extension into computer business graphics, now and in 1986. Please rate on a scale of 1 to 10, where 10 is most important and 1 is not important at all.

	1981	1986	Don't know
Rating	____ 373	____ 374	____ 375

b. Is your company using computer business graphics today? If not, will business graphics be in use in 1986?

	1981	1986
Yes	376 ____	____ 377
No	____	____

ELECTRICAL VENDOR OUTLINE

I. GENERAL

II. MARKET GROWTH

III. TECHNOLOGY ISSUES

IV. PRODUCTIVITY IMPROVEMENTS

V. SOFTWARE

VI. CAD/CAM INTEGRATION

VII. MAINTENANCE

I. GENERAL

1. For the purpose of this study, INPUT defines "CAD" as the utilization of computer aids for graphics, analysis, simulation, modeling requirements, documentation, and configuration control in the support of the design function. "CAM" is defined as the utilization of computer aids in the linkage of outputs from design into the manufacturing process through direct control of numerical control equipment, documentation to aid N/C programmers, bills of material, quality control and the mutual exchange of data between manufacturing and design requirements.

2. Do your CAD/CAM systems include design of:

   1e a. ☐ Printed circuit, wire wrap, hybrid boards (PCB)

   2e b. ☐ Integrated circuits (IC)

   3e c. ☐ Both

3. What type of CAD/CAM systems, services, or software do you offer?

TYPE	PROVIDED (X)	RATING 1981	RATING 1986
a. Standalone turnkey system	10	11	12
b. Integrated system tied to data base	13	14	15
c. Software for in-house host system	16	17	18
d. Remote computing services	19	20	21
e. Independent CAD/CAM software packages	22	23	24
f. Other ______________ 25	26	27	28
g. Other ______________ 29	30	31	32

Please rate the above type of systems with respect to what you believe will be the most dominant method of delivering CAD/CAM capability, now and in 1986. Rating on a scale of 1 to 10, where 10 is most prevalent method and 1 is least prevalent method

Comments: ______________________________

____

4. Will you please send a copy of your latest product/services literature and price list to:

   INPUT
   2471 East Bayshore Road, Suite 600
   Palo Alto, CA 94303

5. Will you please furnish us with a list of your users?

6. What percentage of your products/services do you sell directly to end-users?

33 _______%

II. MARKET GROWTH

7. What is the distribution of your installed CAD/CAM systems in the U.S.A. for the following applications:

APPLICATION	1981	1986
ELECTRONIC	34 ____ %	35 ____ %
MECHANICAL	36 ____ %	37 ____ %
CIVIL/STRUCTURAL	38 ____ %	39 ____ %
MAPPING	40 ____ %	41 ____ %
OTHER ____________	42 ____ %	43 ____ %
	100 %	100 %

8. What is your presently installed base of CAD/CAM systems today.

APPLICATION	NUMBER OF SYSTEMS/ SERVICES	$ VALUE OF SYSTEMS/ SERVICES
ELECTRONIC	44	45
MECHANICAL	46	47
CIVIL/STRUCTURAL	48	49
MAPPING	50	51
OTHER 52 ____________	53	54
TOTAL	55	56

9. In your opinion, what will be the average annual growth rate (AAGR) for dollars spent on CAD systems and services in the U.S. between 1981 and 1986.

	AAGR
Electronic 57	____%
Mechanical 58	____%
Civil/Structural 59	____%
Mapping 60	____%
OVERALL 61	____%

Comments: 62 ______________________________

____

____

10. For your product/service segment, what share of the market do you have/expect to have?

Present share 63 ____% 1986 share 64 ____%

11. What is the average cost per workstation for your system?

65 $____ K's 1981 66 $____ K's 1986

12. What is the average cost per hour per terminal for use of the system?

67 ____ $/hr/terminal 1981 68 ____ $/hr/terminal 1986

13. Who are your top three competitors today and in 1986. Please rank in order from 0 to 1, with 1 being foremost competitor.

COMPETITOR (NAME)	RANK
69	70
71	72
73	74

Comments: 75 ____________________

____

14. Please rate the following vendors with respect to their capability to meet market needs for board design or integrated circuits. Rate on a scale of 1 to 10, where 10 totally fulfills requirements and 1 is woefully inadequate.

PCB a.

VENDOR	RATING
1. Scientific Calculations, Inc. - SCI-CARDS 4e	
2. Bell Northern Research, Ltd. - CPS/COPES 5e	
3. Redac Interactive Graphics, Inc. - mini PCB designer 6e	
4. Automated Systems, Inc. - PRANCE 7e	
5. Computervision - AUTOROUTE 8e	
6. CALMA - CARDS 9e	
7. Applicon - IMAGE 10e	
8. MARK REVEL - AUTOMATE 80 11e	
9. Vectron Graphics Systems, Inc. 12e	
10. Control Data Corporation - AIDS 13e	
11. Other 14e ____________ 15e	

I.C. b.

VENDOR	RATING
1. Applicon 16e	
2. Calma 17e	
3. Computervision 18e	
4. Hewlett Packard 19e	
5. Control Data Corporation 20e	
6. Other 21e ______ 22e	
7. Other 23e ______ 24e	
8. Other ______	

Comments: 25e ______

______

______

______

______

______

III. TECHNOLOGY ISSUES

15. What display terminal technology best serves your applications needs today and in 1986. Please rate on a scale of 1 to 10, where 10 is far exceeding application needs and 1 is totally inadequate for application needs.

TYPE	RATING 1981	RATING 1986
STORAGE TUBE	___ 76	___ 77
REFRESH:		
VECTOR STROKE (Calligraphic)	___ 78	___ 79
RASTER SCAN	___ 80	___ 81
HYBRID	___ 82	___ 83

b. In rating the types of display, considering the ability of the display to meet your application needs, how important are memory requirements? Please rate on a scale of 1 to 10, where 10 is very important and 1 is not a consideration at all.

	1981	1986
Rating	___ 84	___ 85

c. How important is price in the decision to select a particular display terminology?

	1981	1986
Rating	___ 86	___ 87

d. What major changes in display terminals do you expect over the next 5 years, and why will the changes come about?

___
88

___

___

16. How important is the use of color in workstation display for the following applications? Please rate on a scale of 1 to 10, where 10 is of paramount importance, and 1 is not important at all.

APPLICATION	RATING	
	1981	1986
Electronic Design	89	90
Mechanical Design	91	92
Civil Engineering	93	94
Mapping	95	96

17. What response times are users of your systems generally experiencing?

97 _______ seconds

b. Is this adequate?

98 Yes _____ No _____

c. If no, what are the requirements?

99 _______ Seconds

d. Comments:

100 ______________________________

____

____

18. For CAD/CAM design applications, which application input devices are most likely to be used in 1986 systems? (List percent of installations using these devices)

light pen _____% 101　　joystick/ball _____% 102

keyboard _____% 103　　tablet _____% 104

touch panel _____% 105　　digitizer _____% 106

touch recognition _____% 107　　other _______________ 103 _____% 109

19. What will be the prevalent system architecture now and in 1986. Please rank in order of relative importance from 1 to 10, where 1 is most important.

CONFIGURATION	RANK ORDER 1981	RANK ORDER 1986
A. CPU AND GRAPHICS PROCESSOR CO-RESIDENT WITH THE WORK-STATION	_____ 110	_____ 111
B. CENTRAL MAINFRAME HOST AND REMOTE GRAPHICS PROCESSOR	_____ 112	_____ 113
C. DISTRIBUTED SYSTEMS	_____ 114	_____ 115
D. REMOTE COMPUTING SERVICES	_____ 116	_____ 117

20. PCB

What is the adequacy of CAD systems for board design, now and in 1986. Please note the systems overall and their individual features. Rate on a scale of 1 to 10, where 10 is completely adequate and 1 is woefully inadequate.

FEATURE	RATING 1981	RATING 1986
a. SCHEMATICS	26e____	27e____
b. PLACEMENT	28e____	29e____
c. ROUTING	30e____	31e____
d. OTHER 32e____	33e____	34e____
e. OVERALL	35e____	36e____

Comments: 37e ____

21. PCB

Please rate the importance of the following features of CAD systems for board design. Rate on a scale of 1 to 10, where 10 is of critical importance and 1 is not required.

FEATURE	RATING 1981	RATING 1986
a. Interactive graphics	38e______	39e ______
b. Alphanumeric I/O for schematic capture and update.	40e______	41e ______
c. Input data checking and error recovery.	42e______	43e ______
d. Quick plot capability	44e______	45e ______
e. High quality plots	46e______	47e ______

22. PCB

What are the importance of the following libraries?

FEATURE	RATING 1981	RATING 1986
a. Schematic symbol library	48e______	49e______
b. Component parts library	50e______	51e______
c. Mechanical shape library	52e______	53e______
d. Component outline library	54e______	55e______
e. Hybrid chip component library	56e______	57e______
f. Circuit and logic simulation library	58e______	59e______

23. PCB

Do you require:

FEATURE	YES	NO	HOW MANY
a. Multiple data layers 60e			61e
b. Multiple sheet drawings 62e			63e

Comments: ______________________________

____

____

24. PCB

For PCB design, rate the desireability of the following features. Please rate on a scale of 1 to 10, where 10 is vital and 1 is un-important.

FEATURES	RATING	
	1981	1986
a. Automatic component placement to gate level	64e	65e
b. Automatic routing of 2 sided and multilayer boards	66e	67e
c. Output to drive a photo plotter	68e	69e
d. Logic vs. layout check and reports	70e	71e

25. PCB

For wire wrap design, please rate the desireability of the following features.

FEATURES	RATING 1981	RATING 1986
a. Using net list as the basis for wire wrap and multi wire design.	72e ______	73e ______
b. Automatic placement to minimize wire lengths	74e ______	75e ______
c. Minimize wire changes in design update while maintaining data and design integrity.	76e ______	77e ______
d. Utilities to produce properly formatted N/C wire wrap and multi-tape in standard format.	78e ______	79e ______

26. I.C.

What level of complexity, in terms of number of devices per chip, do you presently require; and what do you project your requirements to be in 1986.

	1981	1986	1990
Number devices per chip (-000)	80e ______	81e ______	82e ______

27. I.C.

Please rate the adequacy of present CAD/CAM systems, overall and by individual features. Rate on a scale where 10 is completely adequate.

FEATURE	RATING		
	1981	1986	1990
a. Circuit cimulation	83e ______	84e ______	85e ______
b. Functional and logic simulation	86e ______	87e ______	88e ______
c. Topography verification (Schematics)	89e ______	90e ______	91e ______
d. Design rules checking	92e ______	93e ______	94e ______
e. Testing	95e ______	96e ______	97e ______
f. Mask modifications	98e ______	99e ______	100e ______

28. What are the cost effective balances of intelligence between terminal, local processor and central processor:

Now 118 ____________________

____

____

And in 1986 119 ____________________

____

____

Comments: 120 ____________________

____

____

29. Do you offer end-user training on your CAD/CAM system?

Yes _____ No _____ 121

b. How long does it take to train a new user to:

1. Initial use _______ weeks 122

2. Complete proficiency _______ weeks 123

30. In what fields have improvements in productivity been the greatest? Please rank order on a scale of 0 to 1, where 1 is the greatest improvement.

FIELD	RANKING
ELECTRONIC	______ 124
MECHANICAL	______ 125
CIVIL/STRUCTURAL	______ 126
MAPPING	______ 127

31. What is the importance of the following benefits attributable to CAD/CAM. Please rate on a scale of 1 to 10 and indicate the degree of improvement attained.

BENEFITS	RATING	IMPROVEMENT FACTOR TIMES
a. Reduced design labor 101e	______	102e ______
b. Less computer time 103e	______	104e ______
c. Shortened design span 105e	______	106e ______
d. Achieve more complex product 107e	______	108e ______
e. Better product performance 109e	______	110e ______
f. Other 111e ______	112e ______	113e ______
g. Other 114e ______	115e ______	116e ______

32.a. Describe how productivity gains associated with CAD/CAM implementation can be measured.

117e

b. What has been your general experience with improved productivity?

118e

SOFTWARE

33. What application software do you currently offer for your turnkey CAD system? (Please list by name and give end-user's purchase pricing)

119e

34. What do you believe the major new software developments will be in 1986?

a. System software 132 ______________________________

____

____

b. Application software 133 ______________________________

____

____

35. Will independent software vendors have any impact upon CAD systems during the next several years?

Yes _____ No _____ 134

Rated on a scale of 1 to 10, how important are these vendors to the future of CAD/CAM systems?

_____ Rating 135

Comments: 136 ______________________________

____

____

36. Are you familiar with the following government programs relating to electronic design and manufacturing, and if you are what impact do you see them having on the industry.

a. Very High Speed Integrated Circuit (VHSIC) Program of the office of the under secretary of Defense for Research Engineering

120e Yes ☐ No ☐

Impact: 121e ______________________________

____

____

b. Electronics Computer Aided Manufacturing (ECAM) of the Department of the Army.

122e Yes ☐ No ☐

Impact: 123e ______________________________

____

____

c. The Information Processing Techniques Office of DARPA sponsored research on integrated circuit design.

124e Yes ☐ No ☐

Impact: 125e ______________________________

____

____

d. Other 126e ______________________________

37. I.C.

Please identify which CAD/CAM software packages, and documentation you use (or utilities used in CAD/CAM environment). Rate them on a scale of 1 to 10, where 10 is outstanding and 1 is completely inadequate.

SOFTWARE PACKAGE	USE		RATING APPLICATION	DOCU-MENTATION
	YES	NO		
a. "Database Manager" 127e			128e ______	129e
b. NASTRAN (Finite element modeling) 130e			131e ______	132e
c. ISPICE (NCSS Timeshare) 133e			134e ______	135e
d. SPICE 136e			137e ______	138e
e. SCICARDS 139e			140e ______	141e
f. STICKS (Symbolic layout for LSI) 142e			143e ______	144e
g. PRANCE 145e			146e ______	147e
h. TEGAS Logic Sim (digital) 148e			149e ______	150e
i. LOGCAP Logic Sim (digital) 151e			152e ______	153e
j. COMPACT (Circuit Sim) 154e			155e ______	156e
k. Other ______ 157e			158e ______	159e
l. Other ______ 160e			161e ______	162e
m. Other ______ 163e			164e ______	165e
n. Other ______			______	
o. Other ______			______	
p. Other ______			______	

VI. CAD/CAM INTEGRATION

38. STATUS OF CAD/CAM INTEGRATION

a. How far has industry progressed toward CAD/CAM integration now, and how far do you expect it to be in 1986? Please rate on a scale of 1 to 10, where 10 is completely integrated systems and 1 is no progress at all.

	1981	1986
Rating	____ 140	____ 141

b. To your knowledge, what results have actually been obtained towards integrating CAD and CAM?

____ 142

____

VII. MAINTENANCE

39. Do you offer hardware maintenance through:

____ 143 A monthly contract $ ____ 144 /month

____ 145 A time and materials arrangement $ ____ 146 /month averaged

____ 147 Contract with third party

____ 148 Do not offer hardware maintenance

____ 149 Other (please specify) ____________________ 150

____

40. Is the software supported through:

____ (151) A monthly maintenance fee $____ (152) /month

____ (153) A time and materials arrangement $____ (154) /months averaged

____ (155) No charge

____ (156) Do not offer software maintenance

____ (157) Not applicable to our products/services

____ (158) Other (please specify) ____________ (159)

____

41. How would you rate the overall quality of the maintenance you provide? Please rate on a scale of 1 to 10, where 10 is superior and 1 is completely inadequate.

Hardware ____ (160) Software ____ (161)

If less than 4, comment. (What do the users request that is not being provided)

________________________________ (162)

____

____

42. What levels of response are you presently providing for the following maintenance characteristics?

	Actually Experienced		Minimum Acceptable	
	Hdwre	Sftwre	Hdwre	Sftwre
a. Mean time to respond (hours)	163	164	165	166
b. Mean time to repair (hours)	167	168	169	170
c. MTBF (hours)	171	172	173	174
d. Percent uptime (%)	175	176	177	178

43. What percent of the total purchase decision for future CAD/CAM systems will be based on the quality of maintenance service a vendor provides?

______%
179